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Methods for Air Photo Interpretation and Mapping of Forest Ecosystems in Northeastern Ontario

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Natural Resources Canada
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This file report is an unedited, unpublished report submitted as partial fulfilment of NODA/NFP Project #4020, "Development of methods for Forest Ecosystem Classification (FEC) mapping for Northwestern Ontario".

The views, conclusions, and recommendations contained herein are those of the authors and should be construed neither as policy nor endorsement by Natural Resources Canada or the Ontario Ministry of Natural Resources.

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Methods for Air Photo Interpretation and Mapping of Forest Ecosystems in Northeastern Ontario

Final Technical Report

NODA Project Number 4020

DRAFT

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Abstract

The forest ecosystem classification system (NE-FEC) for northeastern Ontario provides an ecological framework for accumulating knowledge gained by management and research activities. Application of this knowledge in a spatial context requires the ability to inventory and map ecological units, such as site types and vegetation types.

Forest ecosystem mapping exercises were conducted in two boreal landscapes. The first was located in the Great Clay Belt and was dominated by peatlands and lacustrine clay uplands. The second was located near Timmins, and was dominated by coarse-textured till and Glaciofluvial landforms. Ground control points in linear transects were used to develop and test photointerpretive models for black and white, 1:20 000 scale air photographs (standard forest inventory photographs) and for 1:10 000 scale supplementary color photographs. Forest ecosystems were mapped at 1:20 000 scale for representative Ontario Base Maps (OBM: 10,000 ha area) from each study area, using various combinations of different types of imagery and existing inventory.

This report describes the methods used for field sampling, photo interpretation and mapping of forest ecosystems, including: sampling intensities needed to develop photo models and test reliability of maps; the influence of scale, landscape variety, and type of imagery on reliability of mapping; costs and level of effort required to obtain different levels of reliability; and the relationship of forest ecosystems to existing land resource inventories (Forest Resource Inventory, soil and geological maps).

Tools and aids for interpreting NE-FEC site types on standard inventory (black and white 1:20 000 scale) and supplementary color air photographs are presented, including tables of air photo characteristics, and interpretive keys. Patterns of occurrence of NE-FEC site types in the landscape are discussed, and examples are presented of topographic sequences of site types, on landforms commonly found in northeastern Ontario.

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Acknowledg~~e~~ments

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- Mr. Kent Virgo, and Mr. Jeff Leach, Spruce Falls Inc., for assistance with study area selection at Kapuskasing, provision of maps, and helpful advice;
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- Mr. Erik Turk, Lake Abitibi Model Forest, Iroquois Falls, for provision of additional FEC mapping data collected in the Model Forest;
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1.0 Introduction

Mapping contributes to the inventory of local land and forest conditions that is needed by resource managers to make plans and operational decisions. Mapping involves the delineation of polygons that represent areas of relatively homogeneous conditions, and the description of those conditions that are most likely to be met within each polygon. In northern Ontario, most land resource mapping is accomplished by interpolating polygon boundaries and descriptions on air photographs. The interpretation is supplemented by ground truth information, which is used to train photo interpreters, calibrate interpretive models to local conditions, and to check mapping reliability.

This report describes the results of a project to develop methods for photo interpreting and mapping forest ecosystems in northeastern Ontario. A complimentary document, "Guide to the photo interpretation and mapping of forest ecosystems in northeastern Ontario" (Arnup 1996), contains additional resource material for photo interpreting and mapping forest ecosystems in northeastern Ontario, and is based on the results of this project.

The objectives of this project are:

1. To develop methods, tools and aids for the mapping of forest ecosystems using air photographs;

2. To investigate the potential for using existing land resource inventories to predict

the spatial distribution of forest ecosystems for mapping purposes; and

3. To determine the relative cost and accuracy associated with each mapping method.

Readers should be familiar with the complimentary publication: "Field Guide to Forest Ecosystems in Northeastern Ontario" (McCarthy et al. 1994), that describes 22 site types and contains descriptive material on the landforms, soil, and vegetation features that are related to the classification. This report deals mainly with the photo interpretation and mapping of site types, which are mappable, ecological land units. They are appropriate for describing and mapping forest ecosystems at scales compatible with the Ontario Forest Resource Inventory (FRI) and with operational forest management planning.

2.0 Methods

2.1 Selection of Study Areas

Our general study area is the Ministry of Natural Resources' administrative Northeast Region. The Great Clay Belt occupies approximately the northern half of the Northeast Region. This area is characterized by glaciolacustrine plains with generally low relief. Extensive peatland areas have developed on the flat lacustrine plains and are interspersed with uplands on hummocks and ridges, which have fresh to moist, fine-textured silty to clayey soils. Also present are Glaciofluvial features, particularly large esker complexes, many of which are buried under lake deposits or extensively reworked by glacial or wave action, as well as occasional bedrock outcrops.

This terrain contrasts strongly with the landscape in the southern half of the region, which is characterized by extensive glaciofluvial outwash deposits, associated ice-contact landforms, and very shallow to deep, sandy to silty tills, interspersed with bedrock outcroppings. In the southernmost part of the region, the relief is generally greater and more variable. Peatlands and fine-textured lacustrine soils are much less common than in the Clay Belt.

Accordingly, study areas were chosen both within the Great Clay Belt, in the Gordon Cosens Forest, and in the south part of the region, in the Timmins Forest. These management units are both under Forest Management Agreements with industry companies. The Gordon Cosens Forest is managed by Spruce Falls Inc., located at Kapuskasing, and the Timmins Forest is managed by the QUNO Corporation, located at South Porcupine.

At the start of the project, the industry companies responsible for each management unit were approached and asked to supply maps showing areas of interest to them with regard to NE-FEC mapping, to assist in the selection of mapping test areas. Both companies supplied maps for approximately 50,000 ha of land. These areas consisted of approximately 5 to 10 years of future harvest allocations, as described in the Forest Management Plan for each unit. Our purpose in working within these areas was to allow the industry companies to test the usefulness of NE-FEC maps for management purposes, once the pilot mapping exercise was completed.

Within these candidate areas, three Ontario Base Map (OBM) sheets, were selected for test mapping. Each test mapping area consisted of 100 square km (10,000 ha). The areas were selected based on the variety of topographic, soil, and forest stand characteristics present within each map, the representativeness of these conditions for each study area, and company priorities for obtaining NE-FEC information (e.g. harvesting and other management activities planned for the near future). The variety and representativeness of ecological conditions within each map sheet were determined through discussions with industry staff, and by examining existing soil and geological inventories and maps, OBM topographic contour maps, and Forest Resource Inventory (FRI) stand maps.

Map sheets that were representative of ecological conditions in each management unit were selected: two map sheets in the Kapuskasing area, and one map sheet in the Timmins area. In the Kapuskasing area, the first map sheet (Figure 1), located in the northern part of the management unit, was characterized by level terrain and extensive wetland areas. The second map sheet (Figure 2) was located in the southern part of the management unit, and was characterized by generally greater relief, a greater proportion of upland conditions, localized bedrock outcrops and pockets of sandy soil materials of glaciofluvial origin.

The Timmins test sheet (Figure 3) contained areas of glaciofluvial outwash on level terrain, bedrock outcrops, and stony to bouldery, silty to sandy tills, on areas of moderate to steep relief. Total relief over the Timmins test map area was approximately 100 m compared to 30 m for the Kapuskasing test maps.

Figure 1. Location of the NE-FEC test mapping area in the Timmins Forest.

Figure 2. Location of the first NE-FEC test mapping area in the Gordon Cosens Forest, Kapuskasing area.

Figure 3. Location of the second NE-FEC test mapping area in the Gordon Cosens Forest, Kapuskasing area.

2.2 Ground Truthing

Air photos and existing land resource inventories were examined for each OBM test map to determine potential locations for ground sample points. Linear transects from 1 to 4 km in length were selected such that the widest possible range of landform, soil, stand, and site conditions would be sampled, within access limitations. The transects were located on air photos, such that topographic slope sequences were traversed, and were then transcribed onto base maps. To increase the scope of the sampling program, additional transects were selected within the candidate areas supplied by the companies, but outside the three test OBM sheets.

Sampling was conducted at regular 50 m intervals along the linear transects. At each sample point, NE-FEC site types and vegetation types were recorded (at the time the sampling was conducted, a key to soil types for northeastern Ontario was not available). At each sample point, notes on the forest cover, landform features, soil conditions, and vegetational boundary changes were taken, to facilitate air photo interpretation.

Each sample point was spatially referenced using a hand-held Global Positioning System. Using the position averaging feature of the GPS, estimated position errors of approximately 20 to 50 m can be achieved with the hand-held unit. The GPS records a three dimensional coordinate (latitude, longitude and altitude) when sufficient three-dimensional satellite coverage is available, or a two-dimensional coordinate otherwise. Satellite coverage varies from day to day and during the course of any particular day, which affects the accuracy of georeferencing. Tests conducted using the GPS units at known benchmarks indicated a maximum error of +/- 50 m, with 90% of samples having position errors less than +/- 20 m.

2.3 Data Management

Sources of ground truth information for the project are listed in Table 1. The ground sample transect data collected during this project, and similar data collected during an NE-FEC mapping project sponsored by the Lake Abitibi Model Forest, were entered onto computer databases. Each transect was drawn onto air photos, OBM-based FRI stand maps, NOEGTS maps, and CLI maps. The FRI stand listings, and the NOEGTS and CLI legend information was added to the sample point database by transcribing the map information for polygons associated with each NE-FEC sample point. This resulted in a combined database containing NE-FEC attributes, georeferencing information, FRI stand attributes, and soil attributes derived from the NOEGTS and CLI. This database was used to develop predictive algorithms using FRI and soil map attributes, and to test the predictions against the actual site type conditions determined on the ground.

Additional test data were obtained from pre-cut survey information (1984-1990) collected by Spruce Falls Inc., at Kapuskasing, which consisted of sample points installed in FRI stands at a rate of one sample per 10 ha of stand area. The ecological data used to develop and test the site type classification for northeastern Ontario (McCarthy et al. 1994) were obtained from the Ministry of Natural Resources Ecological Data Repository at Sault Ste. Marie. These data were used mainly to augment the transect information for the development and testing of photointerpretive keys.

Table 1. Sources of ground truth information for the NE-FEC test mapping project in northeastern Ontario.

Source	Study Area	No. Sample Points	Sampling Method	Georeference
NODA 4020	Gordon Cosens Forest	970	Linear transect 50 m spacing	GPS to 50 m accuracy; all points
NODA 4020	Timmins Forest	960	Linear transect 50 m spacing	GPS to 50 m accuracy; all points
Lake Abitibi Model Forest	Iroquois Falls Forest	2,100	Linear transect 50 m spacing	GPS to 50 m accuracy; all points
Spruce Falls Inc.	Gordon Cosens	7,250	Point samples	Located on

1984-1990 OPC	Forest		100 m grid	maps only
ELC Provincial Data Repository (NE-FEC databases)	Northeast Region	903	Point samples	300 plots GPS'ed; other 603 located on maps only
Total samples:		12,183		

2.4 Development of the Air Photo Interpretive Key

Data from the transects located outside the three OBM test sheets were used to build photo interpretive models for NE-FEC site types, on both black and white 1:20 000 scale, and color 1:10 000 scale imagery. The site types encountered along these transects were used as the basis for delineating site type polygons surrounding the transect lines.

These polygons were then examined by three photo interpreters. Each interpreter determined a variety of photo interpretive attributes for each polygon, including position on slope, slope %, topographic variety, stand pattern, tree species composition, grey tone, micro- and macro-drainage patterns, polygon shape and orientation. These interpreted attributes were entered onto a computer database, sorted by site type, and then examined to determine the photo interpretive characteristics that could best be used as the basis for a photo interpretive key. The data was structured such that a discriminant analysis could be conducted to assist in selecting the most appropriate variables for use in differentiating site types.

Based on the results of these analyses, a photo interpretive key to NE-FEC site types was prepared. The key permits the identification of dominant site type conditions within a map polygon once the boundary has been drawn. Related information was also prepared to assist in delineating boundaries under different landform and topographic conditions. It was assumed that polygons could be delineated that were composed of a single site type, with other site types occurring as small areas of unmappable inclusions, comprising no more than 20% of the polygon's area. This required interpreting the 1:20 000 scale black-and-white photographs in considerable detail, often delineating many small polygons, using a minimum polygon size of 1 ha.

2.5 Test Mapping

The photointerpretive key was used as the basis for mapping NE-FEC site types on the three test OBM map sheets. Boundary lines were delineated, and a single dominant site type condition was identified for each polygon within the test sheets. After the initial photo interpretation and mapping was completed, the ground sample transects within the three OBM test areas were overlaid on the NE-FEC maps, and a database was prepared consisting of the predicted site types for each polygon, along with the number of samples for each of the site types occurring within each of these polygons. This database was used to determine the site type composition of each polygon, which permitted the reliability of the photo interpreted sheets to be tested by comparing the predicted site types with actual ground conditions.

2.6 Predicting NE-FEC Site Types Using Existing Inventories and Maps

Existing forest, soil, geological, and topographic inventories and maps provide a useful tool for determining the pattern and relative abundance of site types within a forested landscape. In theory, overlaying a vegetation map (e.g., an FRI stand map) on a soil or geological map (e.g., a Northern Ontario Engineering Geology Terrain data base map) should enable the prediction of site types by combining vegetation and soil attributes that define the site types (Figure 4).

*** place Figure 4 here

Since only inventories and maps with available coverage for a large portion of northeastern Ontario will be useful for broad-scale application in predictive mapping, the following inventories were selected for algorithm development and testing:

1. The Northern Ontario Engineering Geology Terrain Studies (NOEGTS), at 1:100 000 scale;

2. The Ontario Soil Survey/Canada Land Inventory (CLI) agricultural soil surveys, at 1:50 000 scale; and

3. The Ontario FRI, which describes vegetational characteristics, including tree species composition, stand stocking, and stand productivity (Plonski's site class), at 1:20 000 scale.

Algorithms for predicting NE-FEC site types from these existing soil and vegetation inventories were developed based on relationships between features mapped by each type of inventory, and soil and vegetational characteristics of the NE-FEC site types. Reliability of the predictions were tested by comparing the site types predicted from various combinations of the existing inventory map polygons, with the corresponding georeferenced database of ground truth sample points.

3.0 Results and Discussion

3.1 Air Photo Interpretation of NE-FEC Site Types

Never

This section contains tools and aids developed to facilitate the interpretation of site types on air photographs. These include a key to the interpretation of site types on black-and-white, stereoscopic air photographs, at standard inventory scales; detailed notes on using the key; notes on the interpretation of landforms, soil, and site features; a tabular summary of key photointerpretive elements; and notes on the use of color air photographs in interpreting the NE-FEC site types.

3.1.1 Key to the Interpretation of NE-FEC Site Types on Black-and-white Air Photographs

1a. Tolerant Hardwood Forests

Polygon with a stand containing sugar maple, red maple and/or yellow birch, a forest transitional between the Boreal and the Great Lakes-St. Lawrence Forest Regions; found mainly in the southernmost parts of Northeast Region; or on warmer than normal ecoclimates, on upper slopes and crests and south-facing slopes.

Tolerant Hardwood Site Types

A. Sugar maple and/or yellow birch comprise 10% or more of the stand .... ST 16
(Sugar Maple - Yellow Birch)

B. Red maple comprises 10% or more of the stand .... ST 15
(Red Maple Mixedwood)

1b. Boreal Forests

Polygon with tree species typically associated with boreal forest conditions, with no tolerant hardwoods present.

2a. Very Shallow Soils

Bedrock outcrops evident, comprising at least 10% of the polygon area. Bedrock surface features (cliffs, crevices, and fractures) may be evident, with the surface vegetation following these bedrock features closely. Ground surface features appear angular, not smoothed or rounded by soil material.

Stands are very open, with a patchy appearance. Due to variability in soil depth and moisture regime, a wide range of tree species occupy very shallow soils: black spruce, white cedar, and larch on wet sites; red, white and jack pine, and white birch on dry to fresh sites; balsam fir, and white spruce on fresh to moist sites; with pockets of trembling aspen on pockets of deeper soil. Overall the stand is mainly coniferous with hardwoods

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2b. Shallow to Deep Soils

Polygon is not as described in 2a; bedrock outcrops are not evident; the underlying bedrock surface is masked by soil overburden, and ground surface features appear smooth or rounded.

3a. Forested Wetlands

Polygon with the stand dominated by black spruce, white cedar, or larch, or mixtures of these species; on extensive areas of flat, low-lying terrain; on level terrain adjacent to rivers, creeks, streams, and lakes; in localized depressions within upland slopes or bedrock plateaus; or in pockets, fissures or crevices in bedrock terrain; with the internal drainage pattern often well-developed (visible as seepageways, open linear channels, or net-like patterns).

Site Types on Wet Organic Soils

A. Polygon with light to very light-toned (depending on the amount of tree canopy cover) black spruce or larch stands, with stunted trees (site class 4 or less); trees uniformly distributed or sometimes arranged in ribbed or net-like surface features reflecting the surface drainage pattern (usually perpendicular to the direction of water flow); polygon is usually circular or oval-shaped in flat terrain, sometimes irregular in hilly or rugged terrain, depending on the surrounding topography; polygon is nearly always surrounded by other wetland site types .... ST 14 (Black spruce - Leatherleaf)

B. Polygon with pure black spruce stand (occasionally with scattered larch present) with a very smooth and uniform appearance; the black spruce trees are uniformly distributed and have small, circular crowns; stands vary in site class but are typically poor (low site class 2 to 3); may have a stippled appearance resulting from the variety in tree heights; stand sometimes appears to be "concave" because of increasing trees heights from the middle to the edges; often with characteristic, uniform, light to medium gray tones; little or no evidence of internal drainage (few or no linear drainage corridors are present) .... ST 11 (Black spruce - Labrador-tea)

C. Polygon with black spruce, larch, and/or white cedar-dominated stand, often with a small component (10% or less) of any "upland species" (white birch, balsam fir, white spruce, balsam poplar, or black ash); or any stand with more than 20% white cedar; dark-toned, closed-canopy black spruce stand occurring immediately adjacent to rich upland hardwood and Mixedwood stands; stands with many (more than 5) internal, open, linear drainage corridors, oriented parallel to the direction of water flow, or in a net-like or delta-like pattern; polygon often located adjacent to a macrodrainage feature (river, creek or stream) .... ST 13 (Conifer - Speckled Alder)

D. Polygon with black spruce or black spruce-larch stands (scattered white cedar can be present but not comprise more than 10% of the stand), with few to moderate number of internal linear drainage corridors (1 to 5) present; the corridors are open or sparsely treed and oriented in different directions; or a stand without obvious drainage corridors but with many small canopy openings, giving it a rough, mottled or patchy appearance; the stand may contain pockets of smooth, uniform canopy (like ST 11) interspersed with drainage corridors or patchy areas; often intermediate in appearance between ST 13 and ST 11 or containing elements of both in patches; typically found within extensive wetland areas, surrounding a treed or untreed bog, associated with lesser drainage features (intermittent creeks or seepageways), adjacent to ST 13 but further away from the uplands, or adjacent to conifer-dominated uplands on areas of generally low relief

....ST 12 (Black Spruce - Speckled Alder)

3b. Upland Forests

Polygon occurring on a detectable slope, not on wet, flat, low-lying terrain or in a depression, (note that rapidly-drained outwash sand flats occur on level terrain). The tree species composition varies, but a stand component of 10% or more upland species (jack pine, trembling aspen, balsam fir, white birch, white spruce, balsam poplar, red pine, or white pine) is diagnostic of upland conditions. The internal drainage pattern (open, linear channels and seepageways) is usually absent or poorly developed, although it can be moderately well-developed on moist, fine-textured soils.

4a. Moist Soils

Polygon occurring on toe slope positions on moderate to steep slopes, on lower to toe slope positions on gentle slopes (Figure 5), or on any low-lying, level area not occupied by a wetland stand, on gently sloping areas adjacent to wetlands, or macrodrainage features such as lakes, rivers, and creeks, or in draws and drainageways within uplands, which appear as linear or fan-shaped gulleys and channels that appear to be "indented" or depressed within the slope, and in small, bowl-like depressions and level areas within long slopes. The boundary between fresh and moist soils occurs at the point of inflexion of the slope (i.e. the point where the slope gradient changes).

Vegetation indicators include a high stand component of black spruce, scattered pockets or individuals of cedar, larch, balsam poplar, white elm and black ash. The tree species composition usually contrasts with the adjacent uplands (e.g., increasing black spruce component). In general, stands on moist soils tend to have a darker appearance than those on fresh soils, due to higher conifer component, more understory vegetation, and their location in depressional areas or drainageways. Stands on moist soils sometimes have a fine mottled appearance, contrasting to a more patchy appearance of stands on fresh soils (due to larger patches of hardwoods and other species).

Site Types on Moist Soils

A. Black spruce comprises 80% or more of the tree canopy .... ST 8 (Black Spruce - Feathermoss - Sphagnum)

B. Hardwood species (trembling aspen, balsam poplar, black ash, and/or white birch) comprise 30% or more of the tree canopy .... ST 10 (Hardwood - Moist Soil)

C. All other stand conditions, typically conifer-dominated Mixedwood stands with varying components of black spruce, white spruce, and balsam fir. The stand may also contain smaller components of larch, white birch, jack pine, white cedar, and/or trembling aspen .... ST 9 (Conifer - Moist Soil)

*** place Figure 5 here

slope - mr diagram

4b. Dry to Fresh Soils

Polygon with stand/site conditions not as described in 3a: dry to fresh soils are usually associated with crests, upper and middle slopes on elevated terrain; or elevated, gently sloping to level areas (plateaus), or level, sandy outwash flats. Internal drainage features that are associated with a restricted water table (linear drainage corridors, wet depressions, and water pools) are absent.

5a. Sandy to Coarse Loamy Glaciofluvial or Glaciolacustrine Soils

Polygon occurring on sandy glaciofluvial (water-laid) landforms including freely-drained, level outwash plains, ridged or hummocky eskers, esker complexes, kames, kettle and kame sequences, and sand dunes; on sandy lacustrine deposits including beach ridges, and freely-drained sandy lake plains.

These landforms have a poorly developed internal drainage pattern. Surface drainage features (creeks, streams, seepageways, and moist depressions) are sparse. Streams and creeks that are present in terrain with sandy to coarse loamy soils are usually long, winding and sinuous, and follow a sparsely branched, dendritic (tree branch-like) pattern. Bars and oxbows may be apparent along the stream's course. Gullies in sandy soils tend to be shallow and V-shaped, appearing as nick or notch-like gashes.

The vegetation cover often contrasts (e.g., different species, degrees of crown closure, and tree height) with the surrounding landscape. Typical stand types include nearly pure stands of uniformly tall jack pine and/or red pine, with a smooth and uniform appearance; jack pine stands with a black spruce component; conifer-dominated stands with high proportions of red and white pine; pure black spruce stands; or mixed hardwood stands, ranging from pure stands of trembling aspen and/or white birch to mixtures of these species with spruce and fir.

Site Types on Dry to Fresh, Sandy to Coarse Loamy Glaciofluvial or Glaciolacustrine Soils

A. Hardwood species (trembling aspen, balsam poplar, and/or white birch) comprise 50% or more of the stand .... ST 6c (Hardwood - Coarse Soil)

B. Jack pine and/or red pine comprise 90% or more of the stand, which is usually in site classes X, 1, or 2, has a smooth and uniform appearance, and occurs on level outwash, flanks of eskers, lakebed sand plains and deltas .... ST 2a (Jack Pine - Coarse Soil)

C. Jack pine, red pine, and/or black spruce comprise 90% or more of the stand, which is usually in site classes 2 or 3. The jack pine component is greater than the black spruce component. The stand appearance varies from uniform to patchy. Occurs on upper slopes and crests of eskers, kames, abandoned beach ridges, and coarse outwash .... ST 2b (Jack Pine - Very Coarse Soil)

D. Jack pine and/or black spruce comprise 90% or more of the stand. The black spruce component is equal to or more than the jack pine component. The stand typically occurs on middle to lower slope positions .... ST 4 (Jack Pine - Black Spruce)

E. All other stands; typically mixedwoods dominated by trembling aspen and jack pine, with varying components of black spruce, white spruce, white birch, balsam fir, red and white pine .... ST 3b (Mixedwood - Coarse Soil)

5b. Other Soils

Polygon not on sandy to coarse loamy, glaciofluvial or glaciolacustrine landforms.

6a. Fine Loamy to Clayey Soils

Polygon occurring on elevated terrain, on upper to lower slopes within glaciolacustrine or clay till plains, characterized by generally low relief, and consisting of flat or gently undulating plains, sometimes interspersed with long, low hills, oriented in the same direction (drumlinoids), and dissected in places by surface drainage features, including small drainageways, channels, and draws. The boundaries of the fine loamy to clayey soils associated with the Great and Little Clay Belt areas are well-mapped on a variety of geological and soil inventories: refer to these maps to help make this decision. Note that clay soils are uncommon outside the Clay Belt areas, occurring only in enclosed depressions in areas of glaciolacustrine soils, and as scattered pockets of fine loamy to clayey ablation till.

Site Types on Fresh Fine Loamy to Clayey Soils

A. Black spruce comprises 80% or more of the stand .... ST 5a (Black Spruce - Feathermoss)

B. Hardwood species (trembling aspen, balsam poplar, and/or white birch) comprise more than 40% of the stand .... ST 7a (Hardwood - Fine Soil)

C. All other stands, typically mixedwoods with varying proportions of trembling aspen, black spruce, balsam poplar, jack pine, white birch, balsam fir, and white spruce .... ST 6a (Conifer Mixedwood - Fine Soil)

6b. Sandy to Silty Soils

The remaining soil materials are alluvial (riverine) or morainal in origin (tills). Landforms associated with deep till materials include ground moraine (subglacial or basal till), end moraines, and ablation moraine (dump till).

7a. Medium Loamy to Silty Soils

Polygon occurring on silty alluvial soils on gently sloping areas, especially areas adjacent to waterbodies that undergo periodic flooding (these appear as long, linear features along the margins of the waterway, with oxbows and scars of abandoned channels often present adjacent to river or stream channels); on areas of low relief in rolling to undulating till terrain, including loams, sandy loams, or silty tills on middle to lower slopes in hummocky ablation moraine (which is characterized by irregular and variable relief, often with a knob-and-kettle appearance, and frequently associated with collapse features, such as crevasse filings and kames); on ice-contact sediments, such as moraines and eskers (with these landforms the terrain is generally more rugged than with ground moraine, and may include cliffy or jagged ridges); or on gentle to moderate slopes within enclosed depressional areas and valleys, which are sometimes terraced.

Silt materials are highly erodible. Gullies and streambeds in silty materials tend to be deep and U-shaped, with steep gully sides with rounded edges. Near changes in slope, the streams tend to become much dissected, with many branches. Evidence of slumping may be present along streambanks and gullies. The overall drainage pattern is typically a highly-dissected pinnate (feather-like) arrangement.

Reference to geological or soils inventories can help to distinguish medium loamy to silty tills from sandy to coarse loamy tills (e.g., on Northern Ontario Engineering Geology Terrain Study maps (Gartner et al. 1985), the material type for sandy tills is "ts", and for loamy to silty tills, it is "tm" or "t").

Site Types on Dry to Fresh Medium Loamy to Silty Soils

A. Hardwood species (trembling aspen, balsam poplar, and/or white birch) comprise 60% or more of the stand .... ST 7b
(Hardwood - Medium Soil)

B. Black spruce comprises 80% or more of the stand .... ST 5b
(Black Spruce - Medium Soil)

C. Upland conifer species (black and white spruce, balsam fir, red, white and jack pine) comprise 70% or more of the stand .... ST 6b
(Conifer Mixedwood - Medium Soil)

D. All other stands, typically mixedwoods dominated by trembling aspen and jack pine, with varying components of black spruce, balsam fir, white spruce, and balsam poplar .... ST 3a
(Mixedwood - Medium Soil)

7b. Sandy to Coarse Loamy Tills

Polygon occurring on ground moraines; end and recessional moraines; on upper slopes and crests in areas of moderate to steep terrain on ablation tills; or on shallow drift over bedrock.

Ground moraines typically appear flat to gently undulating, usually without abrupt or steep slopes, are often patterned with drumlins, fluting features or small, irregular mounds. The compacted soil is poorly drained, and depressional areas between hummocks often develop organic soils. End and recessional moraines occur on variable relief, typically hummocky to irregular, sometimes forming major landscape features such as large, distinctive, steep-sided ridges or sub-parallel ridges, which vary from 1 to 10 km wide, and from 5 to 100 km long, and are often associated with abrupt elevation changes. Ablation moraine is characterized by irregular and variable relief, often with a hummocky, knob-and-kettle appearance, and frequently associated with collapse features, such as crevasse filings and kames.

Shallow drift over bedrock occurs on bedrock-controlled terrain where the soil material was deposited as a thin blanket, veneer or film, such that the surface relief corresponds to the shape of the underlying bedrock, ranging from gently rolling to rugged, broken, jagged or cliffy. Shallow drift tends to be associated with areas of high relief. Deeper drift deposits occur in pockets or depressions, and on gentle to moderate side slopes, often in conjunction with very shallow soils and exposed bedrock on upper slopes and crests or steep side slopes.

Site Types on Dry to Fresh Sandy to Coarse Loamy Tills

A. Hardwood species (trembling aspen, balsam poplar, and/or white birch) comprise 50% or more of the stand
.... ST 6c (Hardwood - Coarse Soil)

B. Jack pine, red pine, and/or black spruce comprise 90% or more of the stand, which is usually in site classes 2 or 3. The jack pine component is greater than black spruce component. Stand appearance varies from uniform to patchy. Stand occurring on well-drained level plateaus, or on upper slopes and crests
.... ST 2b (Jack Pine - Very Coarse Soil)

C. Jack pine and/or black spruce comprise 90% or more of the stand. The black spruce component is equal to or more than the jack pine component. Stand occurring on middle to lower slope positions
.... ST 4 (Jack Pine - Black Spruce)

D. All other stands; typically mixedwoods dominated by trembling aspen and jack pine, with varying components of black spruce, white spruce, white birch, balsam fir, red and white pine .... ST 3b (Mixedwood - Coarse Soil)

3.1.2 How to Use the Air Photo Interpretive Key

The air photo key is intended for use with stereoscopic imagery at scales ranging from 1:10 000 to 1:20 000. Its use assumes a thorough familiarity with air photo interpretation principles, especially the recognition of tree species, the interpretation of stand characteristics, including FRI site class and stocking, and the recognition of landforms and other physical characteristics of the site.

There are two steps involved in mapping site types on air photographs: 1) Delineate the boundaries of polygons having a relatively homogeneous site type composition; and 2) determine the site type composition of each polygon. The key can be used to accomplish both steps. Prior to undertaking the first step, it is recommended that the key be read in full so that the air photo attributes used to delineate boundaries are understood. The key includes notes on boundary placement at each decision node. Once site type boundaries have been delineated, the key can be used to determine the site type composition of each polygon.

The key is structured in two levels. The first level involves seven decisions based mainly on landform, soil, and physical features. These decisions nodes differentiate:

1. Forests with tolerant hardwood components (i.e. Great Lakes - St. Lawrence transitional forests) from forests characterized by boreal tree species;
2. Very shallow soils over bedrock from deeper soils;

3. Forested wetlands (i.e., forests on wet organic soils) from uplands;
4. Moist soils from dry to fresh soils;
5. Sandy to coarse loamy (glaciofluvial or shallow water glaciolacustrine) soils from other soil types;
6. Fine loamy to clayey soils from other soil types; and
7. Medium loamy to silty alluvial and till soils from sandy to coarse loamy tills.

The second level of the key differentiates individual site types within each level 1 decision node, based mainly on vegetation characteristics. These include tree species composition, site class, and stand pattern features. Tree species composition and site class are determined in the same way as for the Ontario Forest Resource Inventory (FRI). Species composition is based on canopy coverage. FRI site classes are based on information presented in Plonski's Yield Tables (Plonski 1974). The determination of both these attributes can be supplemented by ground cruise information, or by referring to existing FRI maps for the study area. Stand pattern features include the uniformity of heights within the tree canopy, and the size, shape, and distribution pattern of openings in the tree canopy.

The key provides considerable detail. Most photo interpreters will develop their own "checklist" of attributes to increase the speed of interpretation and for convenience. Also, certain photo attributes will vary in importance from area to area, depending on factors such as the quality of imagery, area-specific landform associations, topographic variety, and the frequency of occurrence of site types within a particular landscape.

It is recommended that ground truth information should be used to calibrate and refine the key for a specific locale. This information can be in the form of NE-FEC ground survey information, FRI ground cruise information, as well as existing soil and geological inventories and maps, FRI maps, and topographic maps (e.g., topographic contours provide by Ontario Base Mapping or National Topographic Series maps).

Additional publications that provide useful references for the photo interpretation of wetlands and forest ecosystems include Jeglum and Boissonneau 1977; and Jones et al. 1983.

3.1.3 Notes on the Soil-based Decision Nodes

The level 1 decision nodes in the photo interpretive key require knowledge of the relationships between landforms and soil textures, and their interpretation on air photos. This section provides additional details for this purpose. Reference to soil and geological inventories and maps for the area of interest is also recommended (see Section 4). For more detailed information on glacial history and surficial geology in northeastern Ontario, and on landform identification, the following publications are useful: Baldwin et al. 1990; Barnett 1992; Boissonneau 1966; Evans 1984; Keser 1976; Prest 1963; Sims and Baldwin 1991; and Mollard and Janes 1984).

Sandy to Coarse Loamy Soils - Glaciofluvial or Glaciolacustrine Materials

Landforms

Landforms characterized by coarse-textured soils include outwash sand plains, lake deltas, kettles and kettle lakes, kames, sand dunes, beach ridges, and eskers. Outwash areas are often found adjacent to lacustrine deposits. They consist of a body of water-sorted material that forms a broad plain beyond the margin or former margin of a shrinking glacier, and commonly consist of a number of coalescing outwash fans. Varieties are called outwash terraces, fans, aprons, or valley trains. They appear as flat, uniform plains. Drainage features are usually sparse, but they may be terraced or contain the remnants of glacial stream beds, which appear as a braided network of shallow gullies and terraces. Wind erosion may occur on these sand plains, creating sand dunes.

Deltas, kames, dunes and beach ridges are all examples of raised features that may appear to lie over other terrain, such as flat sand plains or wetlands. These features occur at the margins of old lakebeds and are well-mapped on geological inventories. Long, often curvilinear, shapes and orientations are diagnostic for raised beaches and dunes. A delta is a low, relatively flat, fan-shaped tract of land deposited at the mouth of a river as the river flows into a large, standing body of water.

A kame is a short irregular ridge, hill, or mound of stratified drift deposited by meltwater in contact with glacier ice. A kettle is a sharply outlined depression in glacial drift created by the melting of a mass of buried ice. Many kettles are steep-sided, bowl-shaped depressions resembling a kettle drum in form. Kame-and-kettle landscape is terrain with irregular topography resulting from the interspersion of hummocks and kettles (holes). This type of topography is often observed in conjunction with kame fields or other glaciofluvial deposits, such as along the sides of eskers or adjacent to outwash plains.

An esker is a long, narrow, sinuous ridge of stratified drift deposited by melt water on, in, or under a glacier. It appears on air photos as a long, steep-sided ridge, varying in length from a few hundred metres to many kilometres. It may be appear to be discontinuous along its length since portions may be buried under lacustrine or till materials that were deposited later. Eskers often form extensive complexes, with delta fans, outwash plains, and kettle-and-kame deposits along their flanks.

The shallow portions of old lake beds are often characterized by sandy materials due to the relatively high-energy environment. Shallow sandy lake deposits occur along the margins of the clay belts and are associated with several shallow lake plains in the south part of northeastern Ontario.

Drainage Pattern

Coarse soils are more freely drained than fine soils. Moist conditions are less common than in fine soils, occupying a small fraction of the coarse loamy landscape. They tend to be associated with lower and toe slope positions, and are rarely found on middle slopes except on very gentle gradients in areas of low relief. The point of inflexion in concave slopes located near the bottom of ridges and hummocks usually corresponds to the point where water begins to accumulate and moist conditions are found. These lower slope positions are often associated with gentle to almost level terrain.

Fine Loamy to Clayey Soils - Glaciolacustrine or Clay Till Materials

Landforms

Fine loamy to clayey soils are commonly associated with the deep-water portions of proglacial lakes. They occur mainly in the Great Clay Belt in the northern part of

Northeast Region, and in the Little Clay Belt in the south part of Kirkland Lake District and the New Liskeard Area. Parts of the Great Clay Belt were modified by a re-advance of the glacial sheet, however, the texture and appearance of the resulting till material and the unmodified soils of lacustrine origin are essentially the same. Towards the margins of the Great Clay Belt, the soil materials are more typically silty or sandy due to the more active nature of the shallower water. On the margins of the Clay Belts, the fine soils are occasionally interspersed with bedrock hills that were above proglacial water levels. These were frequently stripped of soil due to wave action, and appear as knobs with much exposed bedrock and very shallow soils.

Fine glaciolacustrine deposits are characterized by generally low relief. They typically occur as a uniform, flat plain. The surface is generally smooth and level, or gently undulating, and is sometimes interspersed with long, low hills that are oriented in the same direction (drumlinoids). Due to poor drainage they are often overburdened by organic deposits or contain pockets of organic soils in depressional areas. Sandy and clayey lakebeds often have similar topography but can usually be distinguished by drainage pattern and form.

Drainage Pattern

Gullies and streambeds in clay soils tend to be shallow and saucer-shaped, with softly rounded upper slopes. Since they are subject to flooding, gentle levees or shoulders may develop along the sides of streams. Larger drainageways in clay plains tend to have long, regular serpentine or sinuous meanders. The overall drainage pattern is typically dendritic (with tree-like branches) and has relatively few main branches. However, numerous small swales and draws occur within upland areas, feeding into wetland areas or waterways.

Silty Soils - Alluvial Materials

Landforms

Alluvial deposits are associated with clearly visible modern streams or rivers. They usually develop as long, linear features along the margins of the waterway, with level to gently undulating terrain. Oxbows and scars of abandoned channels are often present in sandy or silty textured soil. The patterns that develop are usually related to the parent material texture and the energy level of the flowing water. Alluvial soils next to large modern rivers can also be fine-textured. Silty soils are often found in low areas next to large rivers that undergo periodic flooding.

Drainage Pattern

Silt materials are highly erodible. Gullies and streambeds in silty materials tend to be deep and U-shaped, with steep gully sides with rounded edges. Near changes in slope, the streams tend to become much dissected with many branches, with less branching. Evidence of slumping may be present along streambanks and gullies. The overall drainage pattern is typically a highly-dissected pinnate (feather-like) arrangement. Contrast these gully shapes and drainage patterns with the notch-like slopes and irregular, tightly sinuous meanders of streambeds located in sandy terrain to help distinguish fine from coarse lacustrine materials.

Sandy to Silty Soils - Morainal Materials (Tills)

Landforms

Ground Moraines

Ground moraines typically appear flat to gently undulating, usually without abrupt or steep slopes. The landscape is often patterned with drumlins, fluting features or small, irregular mounds. Kettle holes are uncommon. The compacted soil is poorly drained, and depressional areas between hummocks often develop organic soils.

Drumlins are low, narrow, oval to elongated hills, with a characteristic streamlined appearance, and are usually associated with ground moraines. Groups of drumlins and/or drumlinoid ridges occur in irregular patterns and are oriented in the same direction. Drumlins typically have a blunt face and a gently tapered or fluted end, but the length and general shape is variable. True drumlins always occur in fields (large groups on level terrain), but drumlinoid features, such as crag and tail deposits, may occur singly or in small groups in all types of terrain. In all cases the soil material is deposited oriented in the direction of ice flow.

End and Recessional Moraines

End and recessional moraines occur on variable relief, typically hummocky to irregular. They sometimes form major landscape features such as large, distinctive, steep-sided ridges or sub-parallel ridges, from 1 to 10 km wide, and from 5 to 100 km long. They are often associated with abrupt elevation changes.

Ablation Moraine

Ablation moraine or till is characterized by irregular and variable relief, often with a knob-and-kettle appearance. It is frequently associated with collapse features, such as crevasse filings and kames, and ice-contact sediments, such as moraines and eskers. Terrain is generally more rugged than with ground moraine, and may include cliffy or jagged ridges, depending on the underlying bedrock surface. Due to the greater relief, soil depths typically vary more than with the preceding till deposits. A large-scale perspective is usually necessary to interpret these features.

Shallow Drift over Bedrock

Shallow drift is associated with bedrock-controlled terrain. The soil material was deposited as a thin blanket, veneer or film. The relief corresponds to the shape of the underlying bedrock, ranging from gently rolling to rugged, broken, jagged or cliffy. Shallow drift tends to be associated with areas of high relief, and occur in pockets of deeper soil, in depressions, and on gentle to moderate side slopes, often in conjunction with very shallow soils and exposed bedrock.

Drainage Pattern

Drainage patterns on till materials are either poorly developed, as on compact ground moraines, or develop angular, parallel patterns similar to those found on very shallow soils over bedrock. Drainage patterns on hummocky ablation till and end moraines often develop radial patterns that follow the contours of the hummocks and ridges. Elements of drainage patterns associated with deep sandy or silty soils may be interspersed locally with the bedrock-controlled drainage pattern, depending on the topography, soil depth, and material type. Linear or fan-shaped downslope seepageways, originating from underground springs, may be present.

Soil Textures

The texture of till materials in northeastern Ontario varies from coarse loamy, including loamy and silty sands, to medium loamy, including sandy loams and loams, to silty soils, usually silt loam. Generally, end and recessional moraines and shallow drift over bedrock tend to be coarse loamy textures, while ground and ablation moraines tend to be medium loamy to silty textures, but these soil conditions vary from area to area.

Reference to ground truth information, or to existing geological or soil inventories can help to determine soil texture-landform relationships that are typical for a particular locale.

3.1.4 Table of Air Photo Attributes for NE-FEC Site Types

The following table summarizes key photointerpretive elements use to differentiate the site types. These are more fully described in the photointerpretive key (Section 3.1.1). This tabular summary is intended to facilitate comparisons between site types.

Table 2. Typical photo interpretation characteristics for NE-FEC site types (ST) on black and white, 1:20 000 scale photos.

	Landscape	Photo Interpretative Features			Associated
ST	Position	Pattern/Texture	Grey Tone	Tree Species	ST's
1	Bedrock outcrops and associated shallow soils	Poorly stocked stands, patchy appearance corresponding to variations in soil depth and drainage	Variable- outcrops appear as white mottles or patches	Mixed, mainly conifers: Sb*,Pj*,Ce,L,Pw; At and Bw occasionally	Depends on surrounding soil material and depth
2a	Outwash sands and other glaciofluvial landforms including eskers, delta fans	Smooth texture more mottled appearance with less well stocked (FRI site class 3) stands on coarse sands	Medium grey	*Pj with small Sb component on occasion	2b, 3a, 4, (6c)
2b	Coarse sandy till, coarse outwash, tops of eskers, beaches, kames	Smooth uniform appearance, mottled or somewhat patchy when hardwoods present	Medium grey	*Pj with lesser component of Sb or Bw; also Pr or Pw	2a, 3b, 4, (6c)
3a	Associated with finer glaciofluvial deposits (deltas, flanks	Mottled to patchy appearance	Mottled light to medium	*At, Bw, Pj, Sw, Bf, Sb	6b, 7b, 3b

	of esker ridges); silty lakebed deposits (e.g near margins of Clay Belt; stratified soils (e.g. Sandy Loam/Clay)	reflecting pockets of hardwoods and conifers	grey		
3b	Most commonly found on sandy to coarse loamy till; end or ground moraines; also occurs on coarse glaciofluvial deposits (outwash, eskers, kames); or on sandy lake deposits (shallow water lake plains, old beaches)	Mottled to patchy appearance reflecting pockets of hardwoods and conifers	Mottled light to medium grey	*At, Pj*,Bw, Sw, Bf, Sb	6c, 2a, 2b, 4
4	Imperfectly drained sandy soils associated with glaciofluvial landform, lower slopes on flanks of eskers or kames	Smooth and uniform texture reflecting well stocked stands	Dark Grey	*Pj,*Sb; usually FRI site class 1	2a, 2b, 3b, 6c
5a	Well to imperfectly drained fine loamy or clayey soils, usually on middle slopes or elevated "hummocks"; lacustrine plains or clay till	Smooth and uniform texture reflecting well stocked stands	Dark Grey	*Sb, Bf; (At) usually FRI site class 1	8, 9; uncommon; usually occurs in complexes

Table 2. Typical photo interpretative characteristics for NE-FEC site types (ST) on black and white, 1:20 000 scale photos (continued).

ST	Landscape Position	Photo Interpretative Features Pattern/Texture	Grey Tone	Tree Species	Associated ST's
5b	Well or moderately well-drained soils on loamy textures (sandy loam to silt); on till material; usually on middle slopes	Smooth and uniform texture reflecting well stocked stands	Dark Grey	*Sb, B; (At) usually FRI site class 1	8, 9; uncommon; usually occurs in complexes; sometimes associated with shallow soils
6a	Well or moderately drained soils on fine loamy to clayey soils; lacustrine plains and clay till; on middle to upper slopes and crests of hills	Patchy appearance with smooth (conifer) patches and mottled (mixedwood) patches	Medium grey; with dark and light mottles	Dominated by conifers: *Sw, *Bf, Sb, Pj with scattered hardwoods: *Bw, (At)	5a, 7a, 9
6b	Well or moderately well-drained soils on loamy tills (textures from sandy loam to silt) on middle to upper slopes and crests of hills	Patchy appearance with smooth (conifer) patches and mottled (mixedwood) patches	Medium grey; with dark and light mottles	Dominated by conifers: *Sw, *Bf, Sb, Pj with scattered hardwoods:*Bw, (At)	7b, 5b, 9
6c	Associated with glaciofluvial landforms, rapidly to well-drained sandy or coarse loamy soils; outwash, eskers, kettles, kames, deltas; or sandy lake deposits (shallow water lake plains, beaches)	Mottled to patchy appearance reflecting pockets of hardwoods and conifers	Mottled light to medium grey	*At, Bw, Pj, Sw, Bf, Sb	3b, 4, 2a, 2b

7a	Well or moderately well drained fine loamy or clayey soils on middel to upper slopes and crests; lacustrine plains and clay till plains	Very patchy reflecting mixed nature of stand, dense shrub understory is common	Light grey with darker patches	Hardwood/ Mixedwoods: *At, Bw, with conifer content: Sb, Sw, Bf	10, (9, 6a); 13 (in wet inclusions)
7b	Well or moderately well-drained soils on loamy textures (sandy loam to silt) on middle to upper slopes and crests of hills	Very patchy reflecting mixed nature of stand, dense shrub understory is common	Light grey with darker patches	Hardwood/ Mixedwoods: *At, Bw, with conifer content: Sb, Sw, Bf	10, 6b, 9; with 7a on boundaries between lakebed and till or outwash materials
8	Poorly drained soils on lower slopes, or slightly elevated hummocks within organic terrain	Smooth and uniform	Medium to dark grey	Typically pure Sb stands; with occasional Bf and Bw; FRI site class 1 or 2	11, 12, 5a, 5b

Table 2. Typical photo interpretation characteristics for NE-FEC site types (ST) on black and white, 1:20 000 scale photos (continued).

ST	Landscape Position	Photo Interpretative Features Pattern/Texture	Grey Tone	Tree Species	Associated ST's
9	Imperfectly to poorly drained soils on middle to lower slopes, or hummocky terrain; sometimes interspersed with ST 13, which occurs on organic soil in drainageways, in complex patterns	Mottled, sometimes also somewhat patchy; often a few indistinct linear drainageways	Mottled Medium to dark grey	Mixed conifers: *Sb, *Sw, Bf Ce; occasional Bw, At, Pb; FRI site class 1 or X	rich forests: 13 (wet soils); hardwood-mixedwoods 6a, 6b, 7a, 7b, 3a (fresh soils)
10	Poorly drained soils on lower slopes adjacent to hardwood stands; various soil materials, generally silt or clay	Mottled; not as patchy as ST 7, alder understory; "honeycomb" appearance; often with a few linear drainageways	Light to medium grey	Mixedwoods; Pb is characteristic; Ab, At, Sw, Sb, Bf also occur	7a, 7b, 9, 13
11	Organic soils with stagnant water flow; often in extensive, flat, more or less "circular" low lying areas. Often occurs in complex associations with ST 12 where the organic terrain has some variety in slope or water movement	Very smooth appearance reflecting dense stands of short trees; few shrubs in the understory except Labrador-tea	Light grey	Pure stands of Sb, FRI site class 3 or 2	12, 8
12	Organic soils with moderate water flow often associated with small creeks and drainageways	Mottled appearance reflecting clumped distribution of trees, with numerous drainageways visible as linear openings in the stands; alder understory varies from moderate to	Mottled medium grey with dark patches and some linear openings in the stand	Pure stands of Sb, FRI site class 1 or 2	13, 11

		dense, and is sometime apparent in canopy openings			
13	Organic soils with strong groundwater flow, often occurring adjacent to streams and creeks or directly adjacent to upland areas where water flow is strong, or in linear, low-lying valleys between upland areas	Mottled to patchy appearance, stands are often poorly stocked with extensive blowdown, dense alder understory is usually apparent in openings in the stand; numerous drainageways are visible as linear openings in the stand	Patchy; medium grey with occasional dark mottles and an extensive network of linear openings	Mixed conifer dominated by Sb with Ce or L components; FRI site class 1 or 2	9, 10, 12

Table 2. Typical photo interpretation characteristics for NE-FEC site types (ST) on black and white, 1:20 000 scale photos (continued).

	Landscape	Photo Interpretative Features			Associated
ST	Position	Pattern/Texture	Grey Tone	Tree Species	ST's
14	Treed and semi-treed bogs and fens, unmerchantable stands on deep organic soils	Smooth to mottled	Very light grey to white	Sb,L; usually FRI site class 4	11, 12
15	Generally on upper slopes and crests of bedrock-controlled ridges or plateaus, locally elevated terrain, in warm ecoclimates; often on till materials.	Very patchy reflecting mixed nature of the stand	Patchy; medium grey with light grey canopy openings and some dark patches	Mr is characteristic; otherwise the stand consists of mixed conifers and hardwoods (Sw, Bf, Bw, At)	mixedwoods on ridges: 7b, 6b, 3b; uncommon but scattered through southern Districts
16	Generally on upper slopes and crests of bedrock-controlled ridges or plateaus, locally elevated terrain, in warm ecoclimates; often on till materials.	Somewhat patchy, sugar maple tends to dominate when present; yellow birch usually occurs in mixed stands similar to ST 15	Patchy; medium grey with light grey canopy openings and some dark	Mh or By are characteristic; otherwise mixed conifers and hardwoods (Sw, Bf, Bw, At)	mixedwoods: 7b, 6b, 3b; rare in Northeast Region; only found in southernmost areas

Tree Species: Ab = black ash, Bw = white birch, By = yellow birch, E = white elm, Pb = balsam poplar, At = trembling aspen, Mh = sugar maple, Ms = red maple, Bf = balsam fir, Ce = eastern white cedar, L = larch, Pj = jack pine, Pr = red pine, Pw = eastern white pine, Sb = black spruce, Sw = white spruce.

3.1.5 Interpretation of Color Imagery

Color photographs can be interpreted in the same manner as black-and-white photographs, using the key provided in Section 3.1.1. However, color imagery provides an additional dimension in photo interpretation in that color attributes are more readily distinguished, compared with gray tones. Many tree species are more easily identified on color photographs compared with black-and-white photographs. The understory vegetation is often more apparent on color photographs, particularly in wetland forests with relatively open canopies. Seasonal photographs can also help distinguish certain hardwood tree and woody shrub species.

The following list summarizes typical colors for boreal tree species as a general guide to their identification. For each species, the hue is listed first, followed by a color value (e.g., light, medium, or dark). This summary represents the average appearance of these species on color imagery. Local variation in color will occur as well as variations in the quality of imagery. It is recommended that photographs be calibrated to local conditions by referring to ground truth information for interpretive purposes. For more information on the identification of tree species from crown characteristics, stand and site features, refer to "Recognition of tree species on aerial photographs" (Sayn-Wittgenstein 1978), which contains numerous stereoscopic examples of color imagery; and "Photographic interpretation of tree species in Ontario" (Zsilinsky 1966), which describes tree species identification on black-and-white panchromatic imagery.

Typical Colors for Tree Species (Hue and Value)

Conifers

Jack pine - brownish-green, medium

Red pine - brownish or yellowish-green, medium to light

Eastern white pine - green, medium

Black spruce - green, very dark

White spruce - green, medium to dark

Balsam fir - green, medium to dark

Larch - turquoise, very light

Eastern white cedar - brownish-green, medium

Hardwoods

Trembling aspen - yellowish green, varies from light to medium within most stands

Balsam poplar - brownish-green, medium

White birch - yellowish-green, light

Black ash - yellowish-green, medium

Identification of Wetland Site Types on Color Imagery

ST 11

Sphagnum species on the forest floor has a bright yellow hue on color photographs. Due to the contrast with the darker green hues of the trees, these site types have a distinctive yellowish cast on color photographs.

ST 12

In ST 12, the Sphagnum on the forest floor is usually obscured by the dense shrub layer of speckled alder. Therefore, these stands do not have the yellow hues characteristic of ST 11 and 14. The dense shrub layer is visible in linear drainageways and canopy openings as a uniform, bright green hue.

ST 13

Similar to ST 12, the dense shrub layer present in ST 13 is visible in linear drainageways and canopy openings as a uniform, bright green hue. Also, tree species that are diagnostic of ST 13, including larch and white cedar, have a very distinctive appearance on color photographs. Sometimes, stands comprised of ST 13 have a closed canopy, so that the understory is not visible. This is often the case for ST 13 areas that directly border upland forests, usually in narrow bands. The green color of these stands is usually darker than the adjacent wetland conditions.

ST 14

Due to the abundant Sphagnum mosses on the forest floor, and the general lack of tall shrubs, ST 14 has a yellowish cast on color photographs, similar to ST 11. However, the more open canopy of this ST gives the stand a brighter yellow hue, which is often tinged with reddish hues from the red-colored Sphagnum spp. that are sometimes abundant in these site conditions.

Seasonal Photography

Color photography is normally conducted in the summer months, when the weather is most suitable. The window available for spring and fall photography is usually very short, making this type of photography impractical for most purposes. During the spring, the colors exhibited by many tree species, particularly hardwoods, change with the phenological stage of development. Phenological development of a species is affected by local climate and by genetic factors. Within a local area, individuals or clones of a tree species may exhibit considerable variation in color, making species identification more difficult. Color photography taken in the fall also shows variation within tree species, since the development of fall colors is gradual, and is affected by genetic factors and local microclimate. Therefore, photography taken in the summer, following full leaf flush and development, has the added advantage that the color of most tree species is stable within a local area.

Nonetheless, photography taken in the fall months can be useful for differentiating hardwoods from conifers, especially in areas dominated by wetland forests where the hardwoods occur in at low levels (e.g., as scattered individuals). These may not be easily detected on conventional black-and-white photographs. The presence of these species can help to distinguish, for example, moist from wet soil conditions, that are otherwise similar in species composition. Fall photography may also be useful in distinguishing certain woody shrubs, e.g., upland species such as mountain maple and cherry spp., which turn deep yellow, orange, or reddish hues in the fall, and species characteristic of wetland forests, including speckled alder and willow species, which turn light yellow or brownish hues following the onset of cold weather. This can be useful in distinguishing the boundaries between upland and lowland conditions.

3.2 Distribution of Site Types in the Landscape

Within forested landscapes there are recurring patterns of topography and landforms, which in turn tend to support specific forest canopy types, in relatively predictable sequences. Consequently, site types within a uniform landform or topographic situation tend to be occur together with groups of related site types, and occur adjacent to specific site types along topographic sequences. For example, upland forests grade into moist transitional forests, then into forested wetlands, moving from upper slopes to toe slopes to level, low-lying areas and depressions. Knowledge of these occurrence patterns assists the photo interpreter in predicting the composition of polygons adjacent to a polygon for which the site type composition is known. This is particularly valuable for site types that are less readily interpreted on air photos.

To examine the distribution of NE-FEC site types within the landscape, a table was prepared showing the frequency with which site types occurred adjacent to each other along the linear sample transects (Table 3). This showed that many site types occur adjacent to each other in specific sequences which tend to occur as repeating patterns across the landscape. Several segments of sample transects showing these common patterns are shown in Tables 4 and 5.

Many upland site types move through specific moist transitional site types through to specific wetland sequences. The most common site type associations are listed in Table 6. For each site type, the site types that were most commonly found adjacent to it are listed, in order of frequency. For example, ST 2a occurred most often adjacent to ST 2b, then to ST 3b, and then to ST 4. ST 2a tends to be enclosed by other upland types, and therefore, rarely occurs next to moist transitional or wetland forests.

3.2.1 Toposequences - Examples of Typical Landscapes

This section contains ten topographic sequence diagrams, or toposequences (Figures 6 to 15). Each toposequence represents a typical pattern of site types on commonly encountered landform complexes in northeastern Ontario. The patterns of site types shown on the toposequence diagrams are representative of actual pattern of site types observed within the test mapping areas. The landform complexes represented by the topsequences are:

Glaciofluvial or Shallow-water Lacustrine Landforms (e.g., outwash plain, sandy lake plain, esker complex)

Hardwood - Mixedwood Sequence on Sandy to Coarse Loamy Soil
Jack Pine - Mixedwood Sequence on Sandy to Coarse Loamy Soil

Shallow Drift over Bedrock (e.g., shallow till on rock ridge, hummock, or plateau)

Hardwood - Mixedwood Sequence on Shallow Coarse Loamy to Silty Soil

Morainal Landforms (e.g., hummocky ablation till, ground moraine)

Mixedwood Sequence on Coarse Loamy to Silty Soil
Conifer Sequence on Medium Loamy to Silty Soil

Glaciolacustrine Landforms (e.g., deep-water lake plain)

Hardwood - Mixedwood Sequence on Fine Loamy to Clayey Soil

Conifer - Mixedwood Sequence on Fine Loamy to Clayey Soil

Black Spruce Sequence on Fine Loamy to Clayey Soil

Organic Landforms

Conifer Sequence on Organic Soil

Black Spruce Sequence on Organic Soil

A key to the tree species silhouettes and substrate types used in the toposequence diagrams is provided (Figure 16).

*** place Figure 6 here

Hardwood - Mixedwood Sequence on Sandy to Coarse Loamy Soil

*** place Figure 7 here

Jack Pine - Mixedwood Sequence on Sandy to Coarse Loamy Soil

*** place Figure 8 here

Hardwood - Mixedwood Sequence on Shallow Coarse Loamy to Silty Soil

*** place Figure 9 here

Mixedwood Sequence on Coarse Loamy to Silty Soil

*** place Figure 10 here

Conifer Sequence on Medium Loamy to Silty Soil

*** place Figure 11 here

Hardwood - Mixedwood Sequence on Fine Loamy to Clayey Soil

*** place Figure 12 here

Conifer - Mixedwood Sequence on Fine Loamy to Clayey Soil

*** place Figure 13 here

Black Spruce Sequence on Fine Loamy to Clayey Soil

*** place Figure 14 here

Conifer Sequence on Organic Soil

*** place Figure 15 here

Black Spruce Sequence on Organic Soil

*** place Figure 16 here

Tree species/substrate key

3.3 Reliability of NE-FEC Air Photo Interpretation

To test the reliability of NE-FEC site type mapping, the actual site types present within mapped polygons, based on ground sample information, were compared with the site types predicted by using the photo interpretive model. Sample points along the linear transects were assigned to individual NE-FEC polygons. The dominant site type condition for each polygon was determined. Each test polygon was then assigned a score of one if the predicted site type matched the actual dominant site type, and a zero if it did not. A total of 288 polygons were used for the test database, or approximately 23% of the total polygons on the test map areas.

Reliability test scores were then summed and expressed as a percentage of all test polygons for each study area (Table 7). Using all the test data, accuracy scores from 66 to 73% were achieved. However, these data included polygons with only a few sample points. The small number of randomly-located test samples within these polygons may not be adequate to determine the dominant site type conditions, since the sample points were sometimes located on edges or within inclusions. Therefore, all test polygons with fewer than four ground truth samples were removed from the analysis. This set of polygons resulted in reliability scores from 75 to 85%. This suggests that for the purposes of testing mapping reliability, a ground truth sample of at least four points per polygon should be installed.

Reliability test results for each site type are shown in Table 8. ST's 1, 2a, 6c, 10, 11, and

13 were interpreted correctly in more than 75% of cases. Certain other ST's are difficult to differentiate on air photos, since are similar in appearance to other site types as they have the same canopy characteristics and occur on similar soil and landform conditions. In the Timmins study area, for example, ST's 2a and 2b, which are both characterized by jack pine stands on sandy soils, were difficult to tell apart and were often mistaken for each other. Mixedwood forests on sandy soils, including ST's 3b and 6c, and rich mixed coniferous forests on moist to wet soils (ST's 9 and 13) were also difficult to differentiate. In the Kapuskasing study area, ST's 7a, 7b, and 10, which have similar overstory conditions, but different soil conditions, were also commonly confused. In the peatland forests, "rich-looking" ST 12's were frequently mistaken for ST 13.

By reworking the map legends for each area to express certain polygon types as complexes of these easily confused site types, rather than annotating them with individual site types, the reliability scores can be improved. Creating complexes of site types that are difficult to differentiate on air photos improved reliability scores in both test areas to approximately 88% (see Table 7).

One method for determining whether combining certain site types into complexes would be appropriate is to prepare a degree of error matrix for the site types. An example is provided in Table 9. The degree of error provides an estimate of the errors' significance to the making of forest management decisions, when contrasting the predicted map polygon site type to the actual site type conditions. Since this matrix should be prepared on the basis of the nature of the management decisions that will be made using the map, it should be reviewed by local resource managers. The matrix can be used both to determine acceptable site type complexes for mapping purposes, and to evaluate the level of risk involved in making planning decisions, based on expected errors in mapping.

Our test results indicate that mapping individual site types using black-and-white air photos, at 1:20 000 scale, can be conducted with reliability results ranging from 75 to 85%, depending on the complexity of the terrain. By creating complexes of site types that are difficult to differentiate on air photos, reliability results can be improved to approximately 85 to 90%. We used a ground truth sample of approximately 10% of total polygons to calibrate the photointerpretive model prior to mapping.

To achieve higher reliability in mapping individual site types would require the installation of a more intensive ground truth sample. Resource managers would need to evaluate whether reliability better than 75 to 80% is needed given the increased cost of field work required to achieve this goal. With approximately 640 NE-FEC polygons per map sheet in our test sample, the minimum amount of field work required would be 64 polygons times four samples, or 256 sample points. Assuming an average of 50 sample points per day, this would require approximately 10 man-days (given a two-person crew) of ground truthing time per map sheet.

Table 10 compares average polygon sizes for the NE-FEC test maps, with the equivalent FRI stand maps for the test areas. There were approximately twice as many NE-FEC polygons as FRI stands mapped in both the Timmins and Kapuskasing test areas, and mean polygon sizes for FRI stands were approximately twice that for NE-FEC polygons. The increased number of NE-FEC polygons will correspond with increased map production costs compared with the FRI stand maps (e.g. for digitizing). This indicates that if map complexity similar to that of the Ontario FRI is required, then NE-FEC mapping complexes must be used to reduce the number of polygons, at a map scale of 1:20 000. Conversely, if FRI stand boundaries are to be used as the basis for NE-FEC mapping, then at least two site types must be annotated to each stand to describe approximately 80% of the land area within the stand.

3.4 Predictive Mapping

Predictive mapping involves the use of the map legend attributes within existing inventories to predict the distribution of NE-FEC site types within the map polygons. This approach can use these inventories individually, or in combination by using map overlays. Since site types are classified by using both soil and vegetational attributes, inventories that map soil or vegetational characteristics related to the classification might be used in predictive mapping. Inventories with extensive map coverage across northeastern Ontario include the Northern Ontario Engineering Geology Terrain Studies (NOEGTS) and the Canada Land Inventory/Ontario Soil Surveys (CLI), which map related soil attributes, and the Ontario FRI, which maps related vegetational characteristics of the forest stands. The availability and usage of these inventories has previously been reviewed in two documents: "Catalogue of land resource surveys in Ontario of major value in forest management" (Pierpoint and Uhlig 1985); and "A guide to the use of land information" (Richards et al. 1979).

3.4.1 NE-FEC Relationships with Soil and Geological Inventories

At the first level of division of the NE-FEC site type classification key, six broad soil classes are identified, which are then further subdivided on the basis of vegetational characteristics to the site type level. These six broad soil classes are:

1. Very shallow soils over bedrock, with less than 30 cm of soil material over rock.

2. Organic soils, with more than 40 cm or organic material developed over either bedrock or mineral soil.

3. Very moist, poorly drained, peaty-phase soils, with prominent mottles within 30 cm of the mineral soil surface, or organic materials from 20 - 39 cm in depth developed over mineral soil.

4. Dry to moderately moist, sandy to coarse loamy soils, including all sand, loamy sand, and silty sand textures.

5. Dry to moist medium loamy to silty soils, including all sandy loam, loam, silt, and silt loam textures.

6. Fresh to moist fine loamy clayey soils, including clay loam, silty clay loam, sandy clay loam, sandy clay, silty clay, and clay textures.

Based on the characteristics of these soil classes, a relationship with the NOEGTS map legend characteristics was developed (Table 11). Due to the nature of the NOEGTS map legends and the scale of mapping, there is no direct analogue to the very moist, poorly drained soil class in the NE-FEC.

The CLI maps can be related more easily to the NE-FEC, since analogous soil texture and moisture regime attributes are included in the map legends. A predicted relationship between the soil series mapped by the OSS/CLI and the NE-FEC site types was also developed (Table 12).

3.4.2 NE-FEC Relationships With the Ontario FRI

Vegetational attributes used in the NE-FEC classification key are as follows: the first division identifies forests that are transitional between the Boreal and Great Lakes/St. Lawrence forest regions (Rowe 1972), based on the presence of tolerant hardwood tree species in the forest canopy. Subsequent divisions in the key identify the remaining site types based mainly on the presence of understory plants. Although the FRI does not indicate understory vegetation, many site types are associated with specific assemblages of tree species which can be related to the FRI stand labels. The distribution of tree species within NE-FEC site and vegetation types is shown in Tables 13 and 14 respectively.

In the FRI, the main vegetational attribute that can be related to the NE-FEC site types is the tree species composition of forest canopy. However, within site types with similar canopy characteristics, elements of the FRI related to site productivity and stand pattern may also be useful. These characteristics include Plonski's site class (a measure of site index expressed as classes of height over age) and stocking, a measure of site occupancy based on the relationship between canopy cover and stand basal area.

Two strategies were explored for assigning FRI stands to any NE-FEC site type groups using FRI characteristics. The first, a deductive strategy, uses the NE-FEC vegetation types, which describe the forest canopy in greater detail than site types, as the primary basis for division of FRI stands. Since each vegetation type can occur on more than one site type, this resulted in a series of complexes of site types described by a specific range of vegetation types. A series of FRI sort criteria were developed to predict these vegetation/site type complexes (Table 15).

The second strategy, used an inductive approach to assign FRI stands into site type complexes. This strategy was developed by examining the FRI stand information associated with the NE-FEC ground sample points in our databases. Frequency distributions of FRI attributes by site types were used to determine the most suitable FRI attributes for differentiating site type classes (Table 16).

Both predictive algorithms for the FRI use a systematic approach. That is, the sorting of FRI stands, and allocation of FRI stands into vegetation/site type complexes must be performed in a specific order. With both algorithms, certain site types that have similar forest canopy characteristics cannot be differentiated using the FRI stand labels.

3.4.3 Predictive Mapping Test Results

Predictive algorithms were tested using the NE-FEC mapping database, by using the FRI, NOEGTS, and CLI attributes to assign polygons into one of the vegetation/site type complexes. To test the predictions, the NE-FEC sample points were used to determine a dominant and a subdominant site type condition within each polygon. If more than 50 percent of the sample points within a polygon consisted of a single site type, this site type was assigned as the dominant condition. In approximately 50% of cases, the sample points within FRI stands consisted mainly of a single site type, with a small proportion of the sample points in other site types, which represented small inclusions or edge conditions.

In the remaining cases, polygons contained more than one site type, although one site type was usually more abundant. In these cases, a subdominant site type was assigned when the subdominant condition comprised at least 20 percent of the NE-FEC sample points within a polygon. The predicted site types were compared with the actual dominant and subdominant site type conditions in each stand. Stands were assigned a value of one if the dominant site type condition matched the site type(s) comprising the predicted complex, and a value of zero if it did not. A secondary score was also assigned to each test polygon if the site type complex matched the subdominant site condition but not the dominant.

With the first predictive algorithm for the FRI, 32% of the stands were correctly assigned in relation to the dominant site type. When the predicted condition was allowed to match either the dominant or the subdominant site type condition within the stands, 48% of the stands were assigned correctly (Table 17).

With the second predictive algorithm for the FRI, 39% of the stands were correctly assigned in relation to the dominant site type, and 56% of the stands were correctly assigned when allowed to match either the dominant or subdominant site type condition within each stand (Table 18). A second test of the two algorithms, using an independent data set comprised of the 903 NE-FEC sample plots used to derive the original classification, and the FRI stand attributes associated with each of these samples, yielded a very similar result. In this second test, approximately 35% of predicted site types matched the dominant site type conditions within each stand, using either algorithm. These tests results suggest that FRI attributes cannot be used to accurately predict the site type conditions present within stands. There are two main problems with the algorithms:

1. Differentiating upland mixedwood conditions that occur on different soil types but have similar canopy characteristics, i.e., ST's 3a, 3b, 6a, 6b, 6c, 7a, and 7b.

2. Differentiating pure or largely pure black spruce stands occurring on either upland moist soils or organic soils. These conditions can be associated with any of ST's 5a, 5b, 8, 9, 11, 12, 13, and 14.

Although the algorithms do not perform well overall, there are certain aspects of these that may prove useful. A few specific tree species combinations on the FRI can be used to predict certain site types most of the time. For example, stands in the white cedar working group were always dominated by ST 13. Pure jack pine stands were dominated by either ST 2a or 2b approximately 80% of the time. Therefore, these algorithms may prove useful in predicting the site type composition of certain FRI stands, reducing the proportion of the inventory for which the site types will need to be determined using other, potentially more expensive methods (e.g., air photo interpretation in combination with ground sampling).

To determine if the performance of the FRI algorithms could be improved by adding soil characteristics, algorithms were developed that used a combination of FRI attributes and either NOEGTS or CLI legend attributes to predict site types within FRI stands. These combined algorithms generated essentially the same result as that of using the FRI attributes alone. The failure of the soil attributes to enhance the FRI algorithms is likely due to differences in the scale of mapping of the FRI (1:20 000), NOEGTS (1:100 000) and CLI (1:50 000) maps, and the scale at which site types occur naturally on the landscape (approximately 1:10 000). Map legend errors, and errors due to the presence of inclusions within inventory polygons, are all magnified by these differences in scale between the inventories. In addition there are basic incompatibilities between the inventory legends and the attributes required to classify NE-FEC vegetation and site types.

There are, however, other uses for the existing inventories in mapping NE-FEC site types. These include: using the inventory maps as training tools, to familiarize photo interpreters with the broad landscape conditions within an area to be mapped, and using the inventories as an initial stratification mechanism, prior to undertaking detailed photo interpretation work and to determine the locations of ground truth sampling points. The usefulness of these inventories in this regard should not be understated, since they provide an important calibration tool for the photo interpreter, and help to fill in information for areas where ground truth samples are not available.

Another potential use would be to reinterpret existing polygons, for example, to annotate existing FRI stands with site type attributes through air photo interpretation. This approach would be more cost efficient than mapping from scratch since it eliminates the need for polygon boundary delineation.

To determine if annotating FRI stands with NE-FEC site types would be feasible, the frequency of occurrence of site types within FRI stands was determined. Each of the FRI stands within the study areas were annotated with from one to four site types, depending on the distribution of site type samples within the stands. The total number of the NE-FEC samples that were accounted for by annotating FRI stands with one, two, three and four site types was then determined (Table 19).

Annotating each FRI stand with a single site type, the dominant condition, accounted for 55% of the ground truth samples, which increased to 76% of the ground samples by annotating stands with two site types. With three site types, 87% of ground truth samples were accounted for. This is interpreted to mean that a photo interpreter could examine existing FRI polygons, use the photointerpretive key to assign a dominant and a subdominant site type to each stand, and thereby accurately describe the site type conditions for approximately 75 to 80% of the area of each stand. Our experience suggests that this task could be accomplished in approximately one-fifth the time required to interpret and map NE-FEC polygons from scratch.

The accuracy of the FRI boundaries in delineating areas containing relatively homogeneous site type conditions will vary somewhat from area to area, as illustrated in Table 20. The poorest results obtained by annotating existing FRI stands were obtained in the Kapuskasing study area, where the land base is characterised by a large proportion of stands in the black spruce working group, very similar canopy characteristics. Better results were obtained in the Timmins forest and the Lake Abitibi Model Forest, where the distribution of uplands and lowlands, FRI working groups and different stand conditions was more balanced.

3.5 Mapping Considerations

The ability to map ecological units is important for ecosystem-based local resource management plans. The most important consideration in mapping is reliability. The desired level of reliability depends on the decisions that will be made based on the map. Generally, broad-scale planning decisions require a lower level of reliability than operational decisions. Operational decisions require that the description of an individual polygon be as accurate as possible. Broad-scale planning decisions usually involve grouping polygons together (e.g., to generate total areas for different site type conditions). During this process, mapping errors tend to cancel out.

Reliability is affected by mapping scale, minimum polygon size, the heterogeneity of the landscape, and the skill of the photo interpreter. Decisions regarding map presentation, such as the use of simple and complex map polygons, and mapping inclusions can also affect reliability. Reliability can be estimated by comparing interpreted polygons with ground truth information. Generally, increasing reliability corresponds with increasing cost. To achieve the highest level of reliability, a greater number of polygons must be delineated, and intensive ground truthing is required.

In the photo interpretive key, the factors used to delineate site type polygon boundaries, in decreasing order of priority, are soil depth, soil texture class, soil moisture regime, tree canopy composition, and stand structural elements, including internal drainage features. This order may be altered to take advantage of the best available information, such as existing inventories and maps. For example, site types may be mapped to conform more closely with existing FRI stand boundaries.

The normal minimum polygon size for forest management purposes is 5 to 10 hectares. This corresponds to mapping scales in the 1:10 000 to 1:20 000 range. The test mapping programs have shown that detailed mapping of site types, at 1:20 000 scale, yields approximately twice the number of polygons compared to the number of stands on a corresponding FRI map.

Ideally, an entire polygon is described as a single site type using a closed-legend approach. These simple polygons are relatively uniform within the limits of acceptable reliability. In extremely variable terrain, site type boundaries can vary over short distances, which would make polygon shapes and sizes too complex to map at the chosen scale. In these cases, a larger map scale can be chosen, or the area may be mapped using complex units. Complex map units are labelled with an open-legend approach which allows the designation of more than one site type per polygon, sometimes along with an estimate of each site type's relative abundance. To facilitate interpretation and use of the map, the use of complex map units should generally be avoided wherever possible.

In most land inventory mapping, approximately 20% of a polygon's area can consist of inclusions. These are small, unmappable areas of site conditions that are not shown in the polygon label. Where the nature of the inclusions are known, and where the site conditions represented by the inclusions are substantially different from the mapped dominant site type, these can be indicated by special map legend symbols. Mapping of inclusions is important only where the nature of the inclusion would limit forest management operations within the polygon. For example, small discrete patches of a different site type within the polygon would not normally be limiting to operations since they can be worked around.

Most large-scale mapping program use the interpretation of air photographs to interpolate polygon boundaries and to identify the composition of each polygon. A typical mapping program is an iterative process involving the use of ground truth information to calibrate and validate an air photo interpretive model, until a desired level of reliability is achieved (Figure 17).

To undertake a comprehensive NE-FEC mapping program, the following steps can be implemented:

1. Review all available background information on the study area, including existing vegetation, soil, and geological inventory. Use this information to generate an initial, broad-scale stratification of the area to be mapped.

2. Collect ground truth information. The preliminary stratification of the area will provide a framework for developing an appropriate sampling plan. This sampling is best accomplished using a systematic approach, e.g., linear transects or grids

(Figure 18). The amount of ground sampling is usually a function of available resources, but should ideally cover as many strata as possible with suitable replications.

3. The ground truth information is used to train the photo interpreters and to calibrate the photointerpretive model (e.g., keys and attribute tables) to local conditions.

4. Using the refined photointerpretive model, delineate NE-FEC polygons on the air photos.

5. These delineated polygons provide a framework for collecting additional ground truth information. This validation information is used for reliability checking. These test samples should be located randomly within NE-FEC site type strata. A minimum of four samples should be located in each polygon to be tested. Single point samples should not be used unless it is certain that the sampling point is representative of the dominant site conditions within the polygon. In inaccessible areas, large-scale or color supplementary photography may be useful for checking the interpretation.

6. Compare the validation data with the interpretation of site types on air photographs. If a satisfactory percentage of polygons were correctly interpreted, the map can be produced. If reliability proves unsatisfactory at this stage, the

validation samples can be used to further refine the photointerpretive model. Most errors will be systematic and are easily corrected.

7. Repeat steps 4 through 6 until a satisfactory level of reliability is achieved.

Note that the more times one goes through the loop, the higher the cost of mapping. Test mapping results suggest that a single pass through the steps listed above will yield reliability in the 80% to 90% range, which is satisfactory for most purposes. Higher reliability may be difficult to achieve due to the limitations of mapping scale.

3.6 Mapping Effort

The following table (Table 21) summarizes the approximate levels of effort, in person-days, that will be required to implement the different NE-FEC mapping methods discussed in this report. This summary is intended to provide a guide for the level of resources that will be required for the selected method(s).

*** Place Table 21 here

Costs have not been calculated since this is a function of each agency's or company's salary structure and overhead. The expected results, in terms of mapping output, and map reliability levels, are listed for each mapping method. The time allocations are based on the completion of mapping for an area equivalent to one OBM base map (100 km^2).

Time allocations for computer data handling are based on the production of an inventory database and map legend, but do not include time that would be required to digitize the map polygons using a geographic information system.

4.0 Conclusion

Forest ecosystems can be recognized on air photographs by interpreting landform, topographic, soil, and vegetational features visible on the air photographs that correspond to the soil and vegetational features that define the NE-FEC site types. A dichotomous key was produced for the interpretation of site types on black-and-white 1:20 000 scale air photographs, the type used by the Ontario FRI for producing forest stand maps. The key is intended for use by experienced photo interpreters with a working knowledge of tree species and landform identification, and experience with interpreting forest stand attributes as they are used in the FRI.

In the key, the order of priority of photo interpretive elements used to delineate and identify the composition of site type polygons in the key is as follows:

1. Soil depth, interpreted from bedrock outcroppings and vegetational features;

2. Soil texture class, interpreted from landform type and macro-drainage pattern;

3. Soil moisture regime, interpreted by position on slope, micro-drainage pattern, and vegetational features;

4. Within deep soil texture and moisture regime classes, the NE-FEC site types are interpreted from the forest stand tree species composition, stand productivity, and

stand pattern features.

Descriptive material intended to support the use of the key is provided in this report, and in a companion document, "Guide to the mapping of forest ecosystems in northeastern Ontario" (Arnup 1996).

This key can also be used with color imagery. Attributes that enhance the recognition of site types on color air photographs are summarized. Color imagery for inventory purposes is not widely available in Ontario, due, in part, to problems with consistency of image quality and processing, and increased cost over standard black-and-white imagery. Nonetheless, color imagery can greatly enhance the interpretation of NE-FEC site types, especially in peatland landscapes. It can be used to enhance interpretation in inaccessible areas where ground truth sampling is difficult.

NE-FEC site types occur in the landscape in specific patterns along topographic gradients. Examination of the frequency of occurrence of site types along linear ground sampling transects revealed that the distribution of site types will vary, depending on the landforms and soils that dominate each landscape. This report contains topographic sequence diagrams for landform conditions commonly found in northeastern Ontario, that are based on actual sequences of site types encountered within the test mapping areas.

Test mapping programs were completed to examine the efficiency of several different methods for mapping forest ecosystems:

1. Creating predictive map overlays, that resulted in maps with the existing inventory polygons annotated with site type complexes of 3 to 4 site types;

2. Annotating existing map polygons (e.g., FRI stands), resulting in maps with the existing inventory polygons annotated with 2 to 4 site types;

3. Producing a new NE-FEC map base, with minimal ground truthing, resulting in maps with approximately 50% of polygons labelled with individual site types, and 50% of polygons labelled as site type complexes; and

4. Producing a new NE-FEC map base with intensive ground truthing, resulting in maps with approximately 80% of polygons labelled with individual site types, and 20% of polygons labelled as site type complexes.

The most reliable methods of mapping involved creating a new map, through the air photo interpretation of NE-FEC site type polygons. Depending on the intensity of ground sampling, these methods provided reliability levels from 75 to 90%. These methods also produced more complex maps than the other methods. Compared with Ontario FRI stand maps, the NE-FEC maps contained approximately twice the number of polygons within an equivalent area. Consequently, the costs associated with map production will be higher than with the use of existing inventory.

Annotating existing FRI stand polygons with the NE-FEC site type composition (e.g., ST 8 - 80%, ST 11 - 20%) is a more cost efficient method for mapping site types. Many of the existing FRI polygons enclose areas with relatively homogeneous site type conditions. Although this method results in less detailed maps, containing mainly complex polygons comprised of 2 to 4 site types, the reliability levels that can be achieved are similar to those obtained by producing a new map base.

Predictive mapping using existing inventories appears to be an unsatisfactory method for mapping NE-FEC site types. The reliability levels obtained are too low (less than 50%) for most planning and operational applications. The main problems are the differences in scale of mapping between the various inventories, which leads to cumulative mapping errors when using overlays, and incompatibilities between the elements contained in the map legends (i.e., the mapping classes) for the various inventories, and the ecological features needed to recognize site type differences. Nonetheless, these inventories provide a useful context for training interpreters and for calibrating air photo interpretive models.

When deciding on the most appropriate method for mapping NE-FEC site types, resource managers must balance the effort and cost of mapping against the results achieved. The level of reliability required is determined by the types of management decisions that will be made using the maps. Mapping methods can be combined to achieve greatest efficiency.

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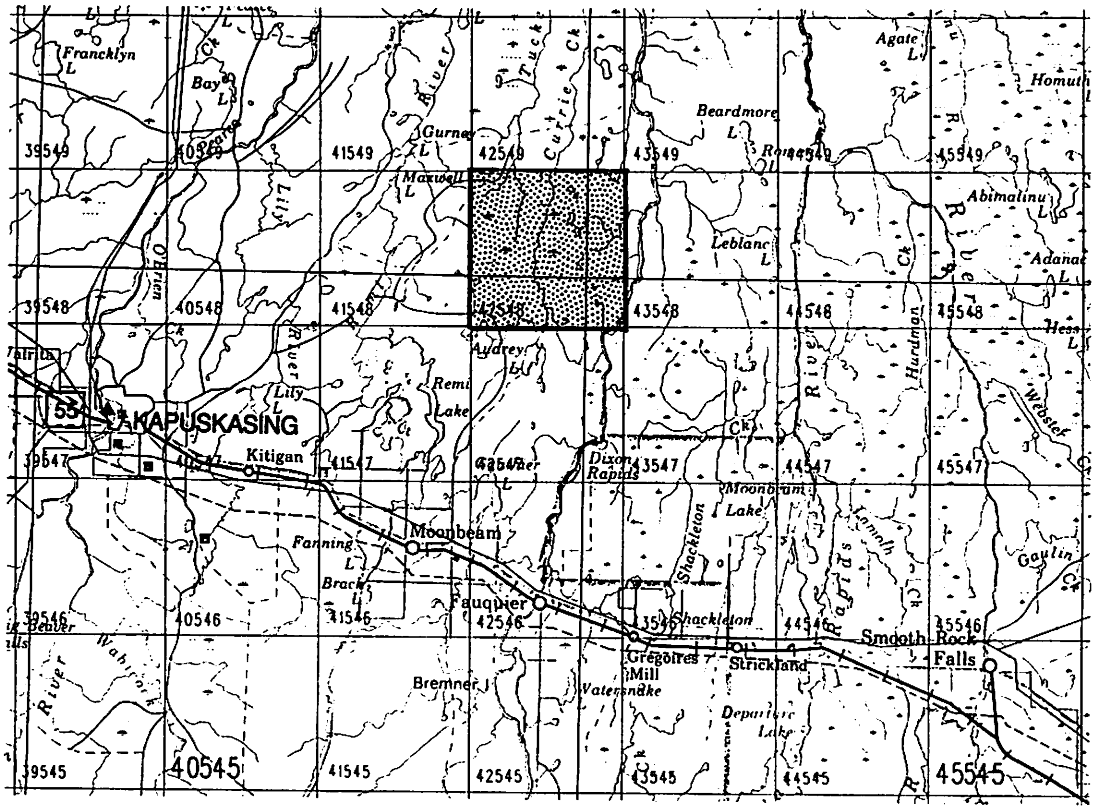
Fig. 1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Audrey L
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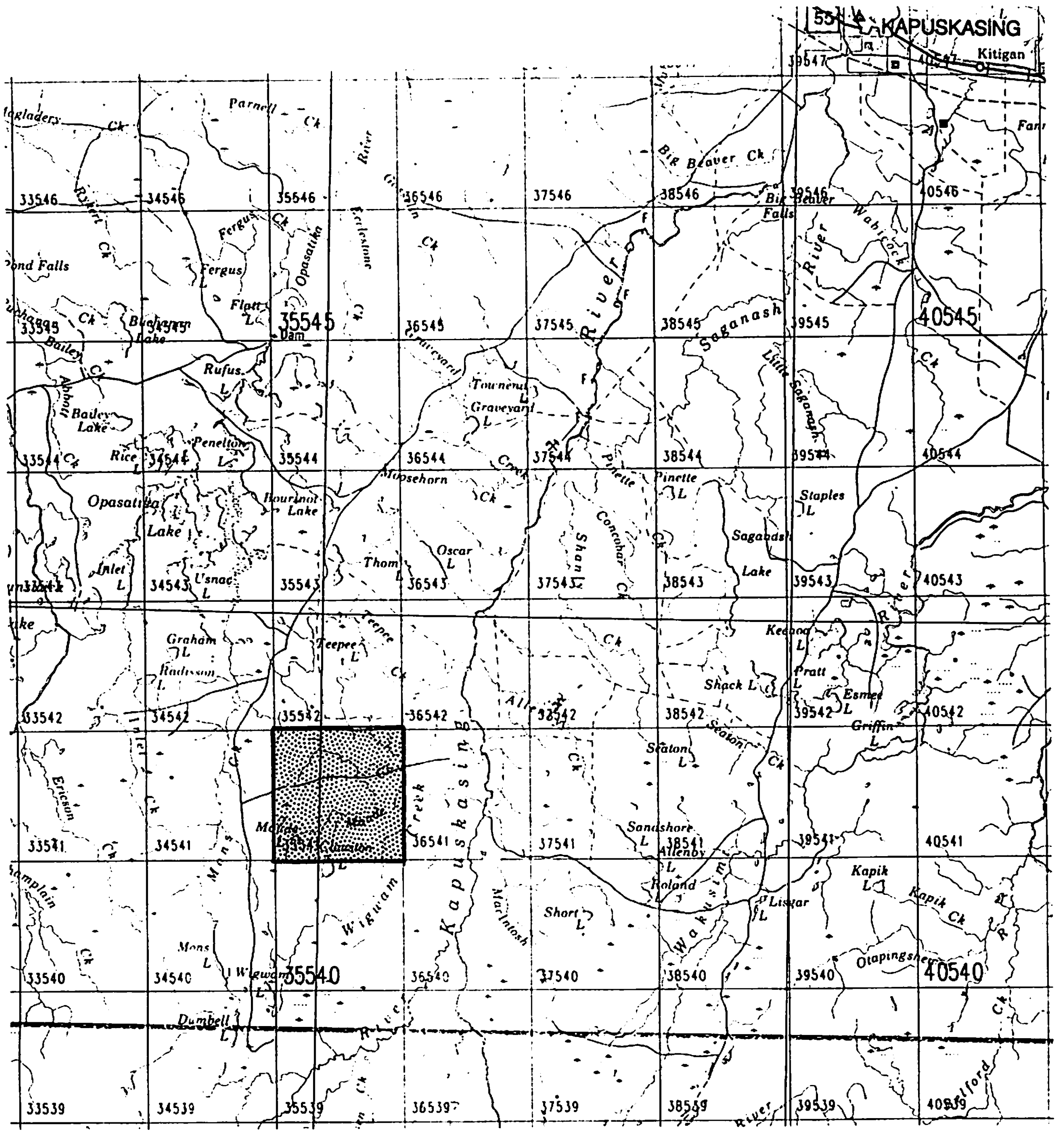
Kitigan
Moonbeam
Fanning L
Brack L
Fauquier
Dixon Rapids
Moonbeam Lake
Shackleton
Gregoires Mill
Strickland
Smooth Rock Falls
Watersnake
Departure Lake
Bremner
Hurdman Ck
Rapids
Webster
Gaulin Ck
River
Wabirook River
Beaver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Little Saganash River
Wakusimi River
Big Beaver Ck
Big Beaver Falls
Wabicock
Mons Ck
Wiguam Creek
Opasatika Lake
Bailey Lake
Rufus L
Fergus L
Penelton L
Rice L
Hourlnot Lake
Inlet L
Usnac L
Graham L
Teepee L
Thom L
Oscar L
Mossehorn Ck
Tournenu L
Graveyard L
Pinette L
Concobar Ck
Shan Ck
Staples L
Sagabash Lake
Keenoa L
Pratt L
Shack L
Esmee L
Griffin L
Seaton L
Sandshore L
Allenby L
Roland L
Lisgar L
Short L
MacIntosh
Kapik L
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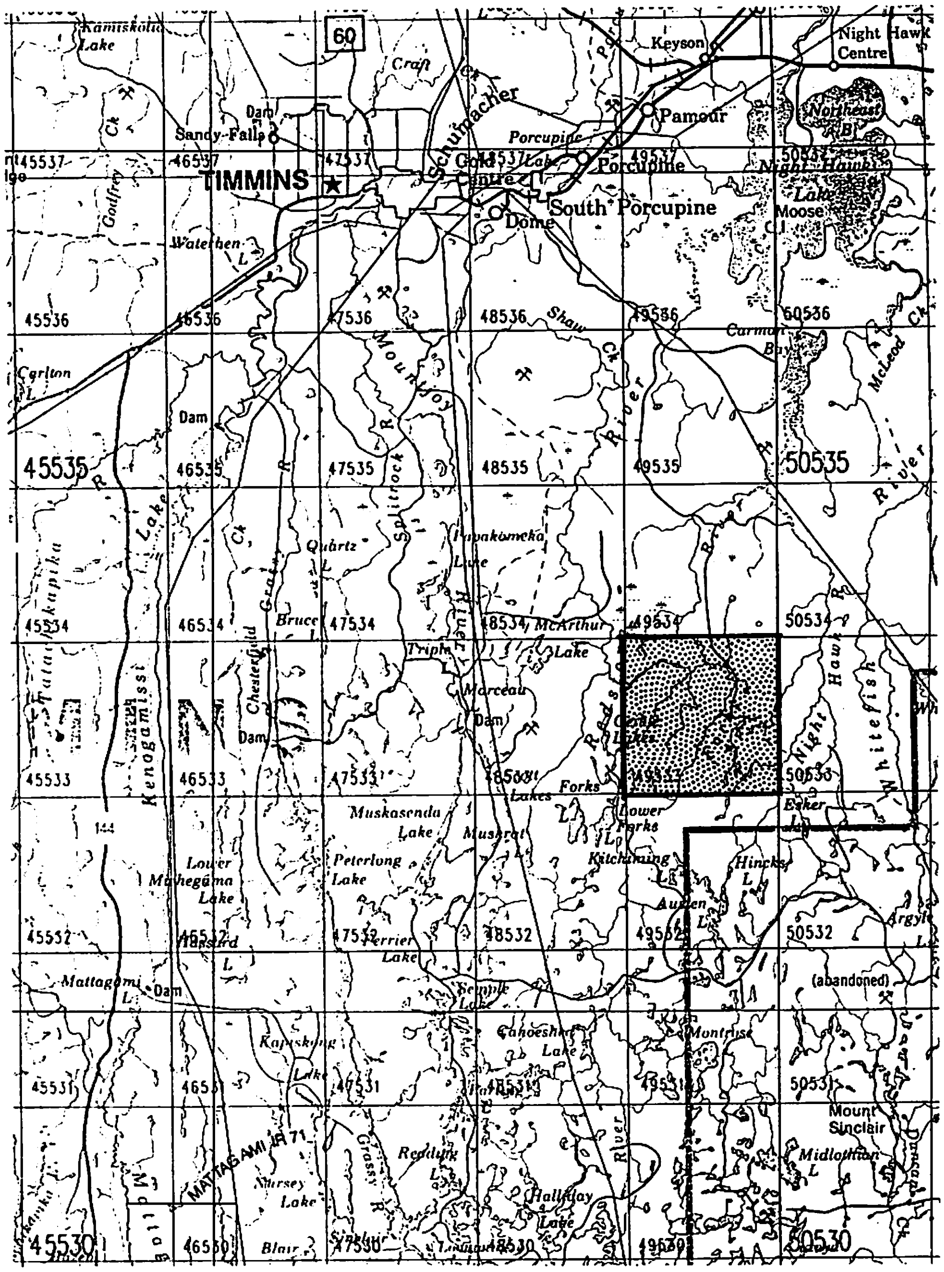
Fig. 3



60
Kamiskotia Lake
Craft
Schumacher
Keyson
Night Hawk Centre
Pamour
Northeast Bay
Sandy Falls
Dam
Porcupine Lake
Porcupine
Night Hawk Lake
TIMMINS
Gold Centre
South Porcupine
Dome
Moose
Godfrey
Waterhen L
45537
46537
47537
48537
49537
50537
45536
46536
47536
48536
49536
50536
Shaw Ck
Carman Bay
McLeod Ck
Carlton L
Mountjoy R
Dam
River
45535
46535
47535
48535
49535
50535
Kenogamissi Lake
Quartz L
Papakomeka Lake
Bruce L
Splitrock
Grassy
Chesterfield
45534
46534
47534
48534
49534
50534
McArthur Lake
Triple
Marceau
Dam
Redstone
Night Hawk R
Whitefish
45533
46533
47533
48533
49533
50533
Forks Lakes
Lower Forks L
Esker L
Muskasenda Lake
Muskrat
Lower Mahegama Lake
Peterlong Lake
Kitchening
Hincks L
Aubrey L
Argyle L
45532
46532
47532
48532
49532
50532
Perrier Lake
(abandoned)
Mattagami L
Dam
Semple Lake
Canoeshed Lake
Montrose
Kapuskasing Lake
45531
46531
47531
48531
49531
50531
Mount Sinclair
Midlothian L
Redding L
Halliday Lake
Nursey Lake
MATTAGAMI IR 71
Grassy R
River
144
45530
46530
47530
48530
49530
50530
Blair

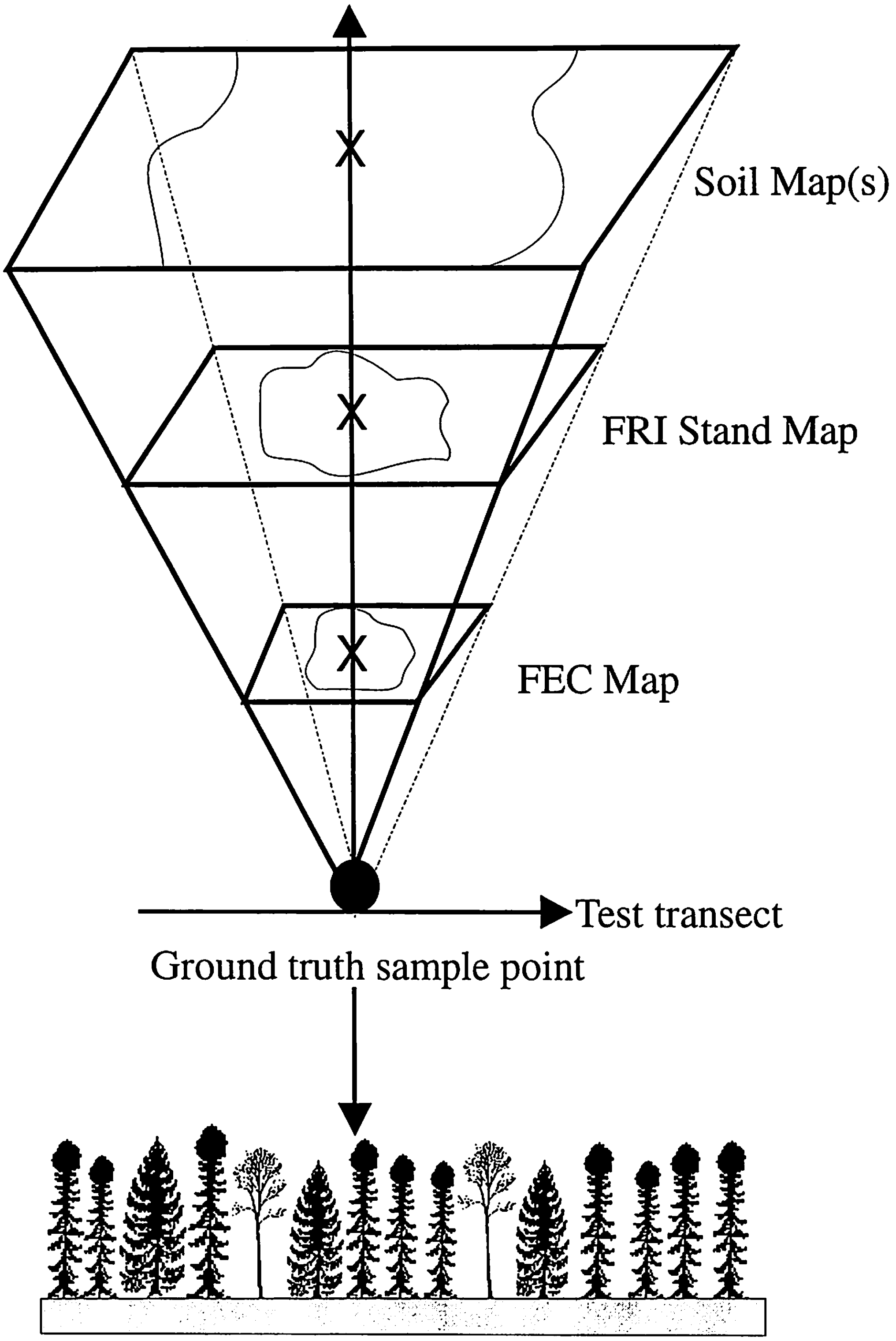


Figure 4. Testing the capability of existing land resource inventories to predict the spatial distribution of forest ecosystems.

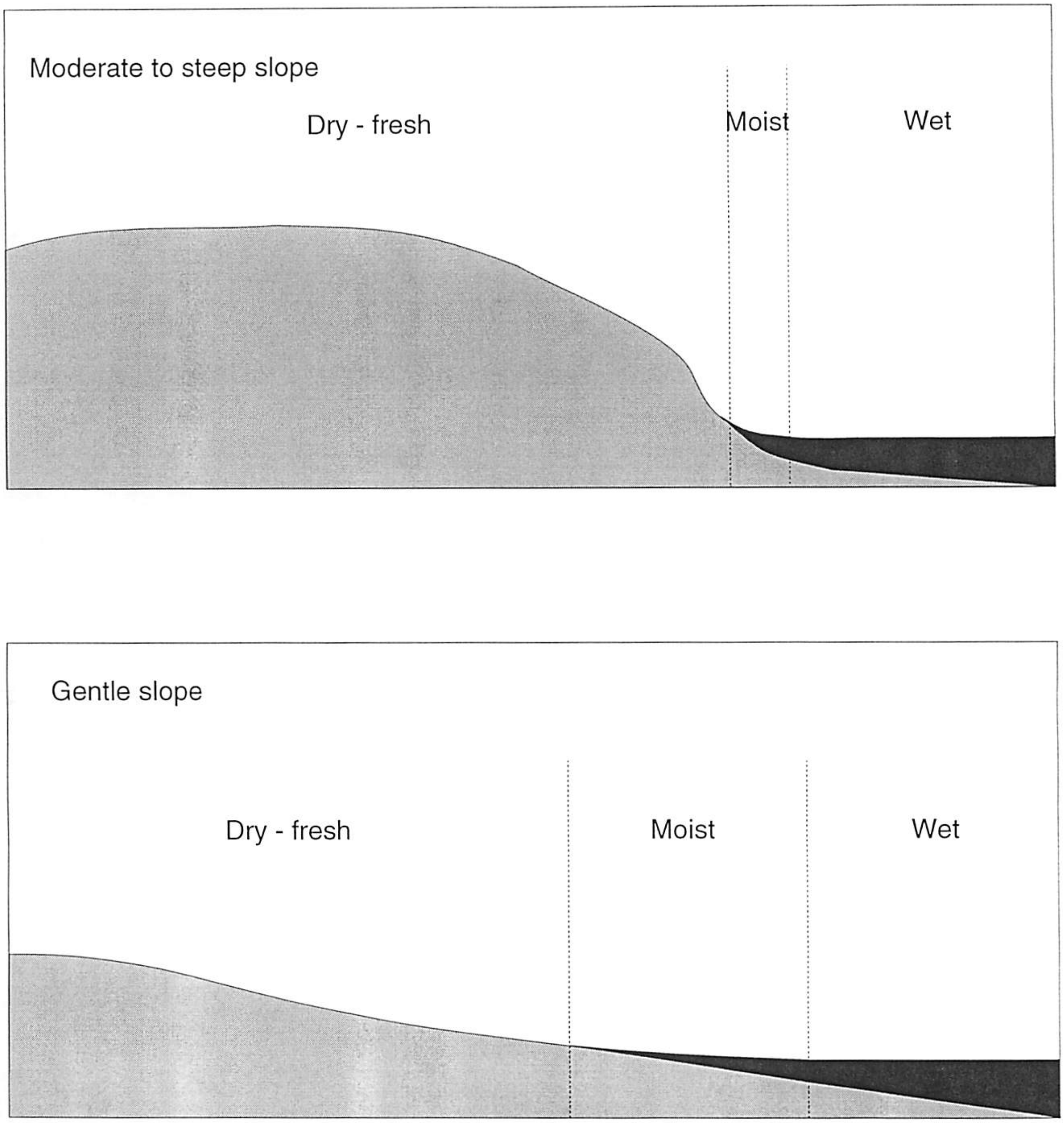
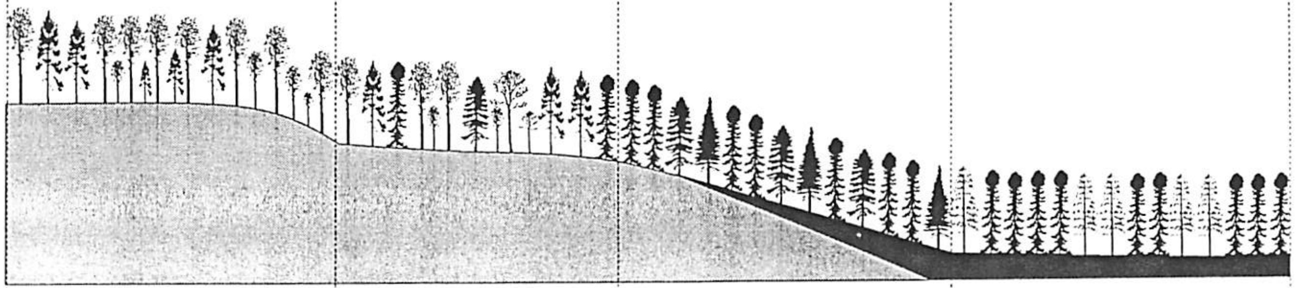


Figure 5. The approximate relationship between slope grade and soil moisture regime.

Fig. 6

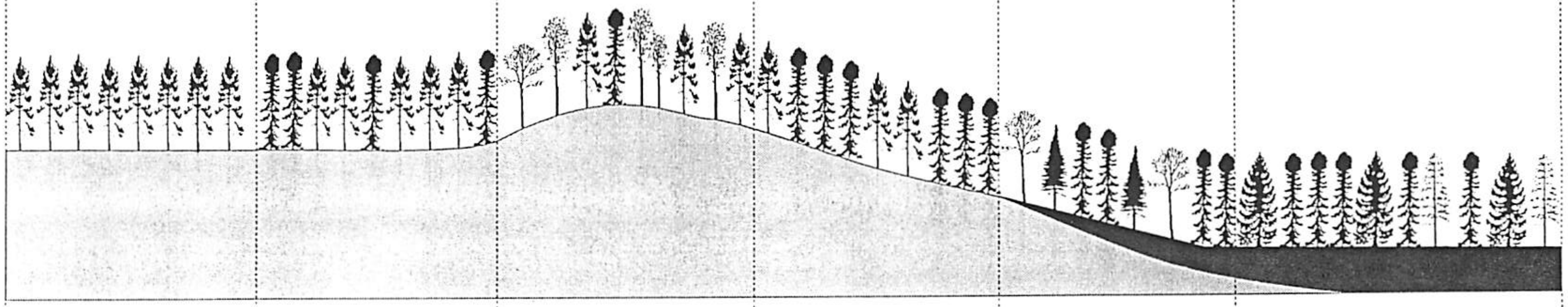
Hardwood - Mixedwood Sequence on Sandy to Coarse Loamy Soil



	Po-(Pj)	**Po-Pj-Sb-Sw-Bw**	**Sb-Sw-Bf**	**Sb-L**
Site type:	3b	6c	9	13
Name:	Mixedwood-Coarse Soil	Hardwood-Mixedwood-Coarse Soil	Conifer-Moist Soil	Conifer-Speckled Alder
Vegetation type:	13	12	7	20
Name:	Trembling Aspen-Black Spruce-Blueberry	Trembling Aspen-Mixedwood	White Spruce-Balsam Fir-White Cedar-Mountain Maple	White Cedar-Black Spruce
Moisture regime:	Fresh	Fresh	Moist	Wet
Depth of organic (cm):	10	5	25	40 - 100
Humus form:	Fibrimor	Raw Moder	Humimor	Humic Peaty Mor
Texture:	Loamy Very Fine Sand	Fine Sand	Silty Fine Sand	Mesic Organic

Fig 7

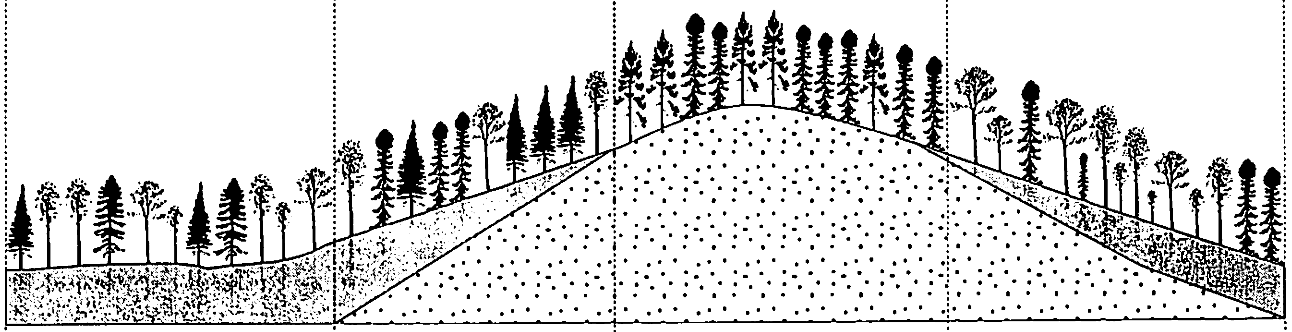
Jack Pine - Mixedwood Sequence on Sandy to Coarse Loamy Soil



	Pj	Pj-(Sb)	Po-Pj-Sb-Bw	Sb-Pj	Sb-Bw-Bf	Sb-Ce-L
Site type:	2a	2b	3b	4	9	13
Name:	Jack Pine-Coarse Soil	Jack Pine-Very Coarse Soil	Mixedwood-Coarse Soil	Jack Pine-Black Spruce	Conifer-Moist Soil	Conifer-Speckled Alder
Vegetation type:	15	16	13	18	7	20
Name:	Jack Pine-Blueberry-Feathermoss	Jack Pine-Black Spruce-Feathermoss	Trembling Aspen-Black Spruce-Blueberry	Black Spruce-Jack Pine-Feathermoss	White Spruce-Balsam Fir-White Cedar-Mountain Maple	White Cedar-White Spruce
Moisture regime:	Fresh	Fresh	Fresh	Fresh/moist	Moist	Wet
Depth of organic (cm):	5	5	10	10	25	40 - 200
Humus form:	Fibrimor	Fibrimor	Fibrimor	Fibrimor		Fibric Peatymor
Texture:	Fine Sand	Coarse Sand	Loamy Fine Sand	Loamy Fine Sand	Silty Very Fine Sand	Organic

Fig. 8

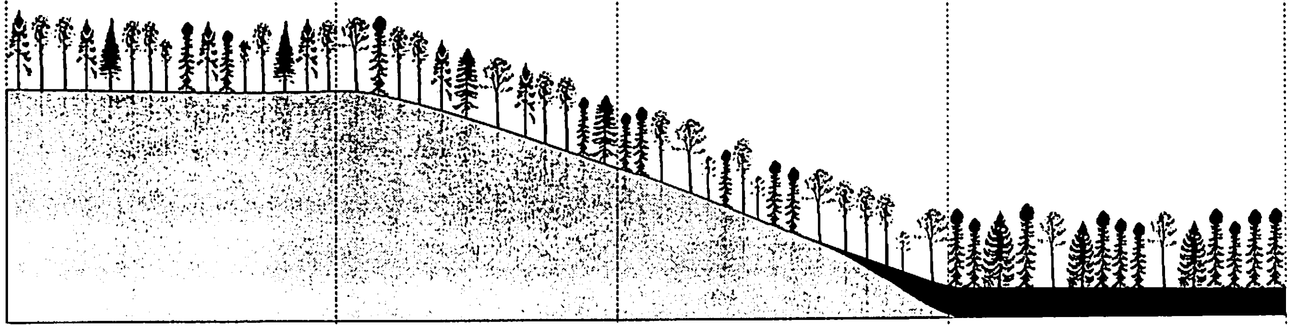
Hardwood - Mixedwood Sequence on Shallow Coarse Loamy to Silty Soil



	Po-Sw-Bw-Bf	Bf-Sb-Bw-Po	Sb-Pj	Po-Bw-Sb
Site type:	7b	6b	1	3b
Name:	Hardwood-Medium Soil	Conifer Mixedwood-Medium Soil	Very Shallow Soil	Mixedwood-Coarse Soil
Vegetation type:	9	8	16	13
Name:	Trembling Aspen-Balsam Fir-Mountain Maple	Trembling Aspen-Black Spruce	Jack Pine-Black Spruce-Feathermoss	Trembling Aspen-Black Spruce-Blueberry
Moisture regime:	Fresh	Fresh	Dry	Fresh
Depth of organic (cm):	5	10	5	10
Humus form:	Raw Moder	Humifibrimor	Fibrimor	Fibrimor
Texture:	Silt Loam	Silt Loam	Rock	Loamy Medium Sand

Fig 9

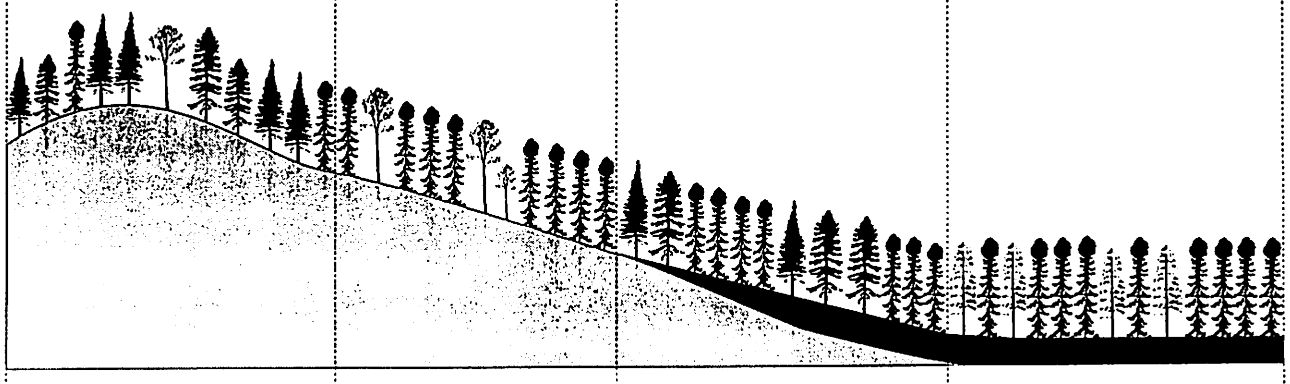
Mixedwood Sequence on Coarse Loamy to Silty Soil



	Po-Pj-Bf-Sb	Po-Pj-Sb-Sw-Bw	Pb-Bw-Sb	Sb-Ce-Bw
Site type:	3a	3b	10	13
Name:	Mixedwood-Medium Soil	Mixedwood-Coarse Soil	Hardwood-Moist Soil	Conifer-Speckled Alder
Vegetation type:	13	13	10	20
Name:	Trembling Aspen-Black Spruce-Blueberry	Trembling Aspen-Black Spruce-Blueberry	Balsam Poplar-Trembling Aspen-Speckled Alder	White Cedar-Black Spruce
Moisture regime:	Fresh	Fresh	Moist	Wet
Depth of organic (cm):	10	10	25	40 - 100
Humus form:	Humifibrimor	Fibrimor	Typical Moder	Humic Peaty Mor
Texture:	Silty Loam	Silty Fine Sand	Silty Fine Sand	Humic Organic

Fig. 10

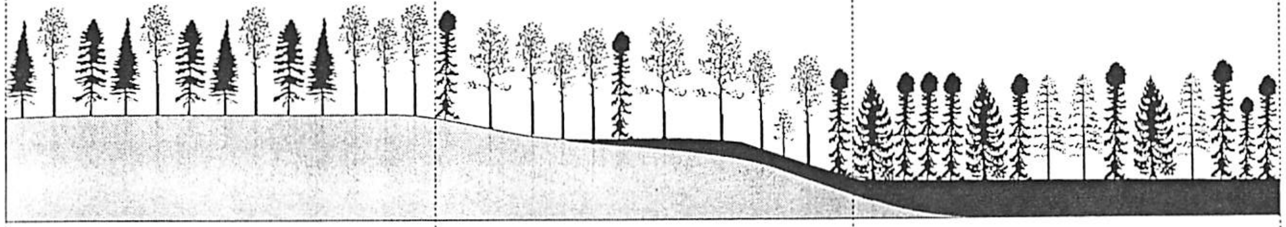
Conifer Sequence on Medium Loamy to Silty Soil



	Bf-Sw-Sb-Bw	Sb-Bw	Sb-Sw-Bf	Sb-L
Site type:	6b	5b	9	12
Name:	Conifer-Mixedwood- Medium Soil	Black Spruce- Medium Soil	Conifer- Moist Soil	Black Spruce- Speckled Alder
Vegetation type:	8	16	9	21
Name:	Trembling Aspen- Black Spruce	Jack Pine- Black Spruce- Feathermoss	White Spruce- Balsam Fir- White Cedar- Mountain Maple	Black Spruce- Speckled Alder- Sphagnum- Stair-step Moss
Moisture regime:	Fresh	Fresh	Moist	Wet
Depth of organic (cm):	10	10	30	40 - 150
Humus form:	Fibrimor	Fibrimor	Mesic Peaty Mor	Fibric Peaty Mor
Texture:	Silt Loam	Fine Sandy Loam	Silt Loam	Fibric Organic

Fig 11

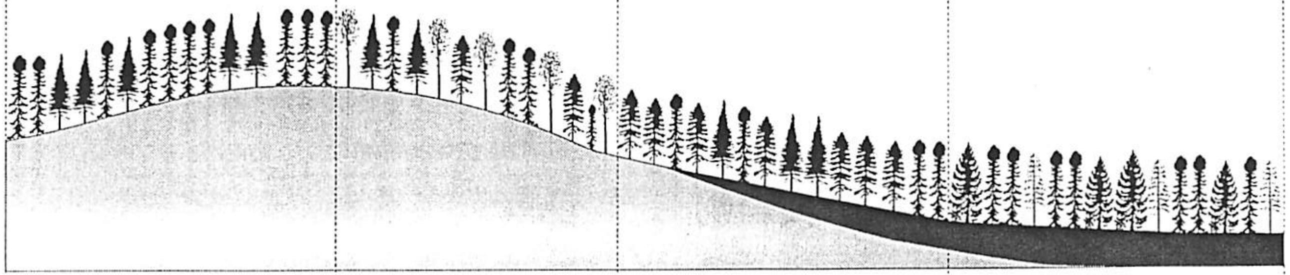
Hardwood - Mixedwood Sequence on Fine Loamy to Clayey Soil



	Po-Bf-Sw	Pb-Po-Sb	Sb-Ce-L
Site type:	7a	10	13
Name:	Hardwood - Fine Soil	Hardwood - Moist Soil	Conifer-Speckled Alder
Vegetation type:	9	10	20
Name:	Trembling Aspen- Balsam Fir- Mountain Maple	Balsam Poplar- Trembling Aspen- Mountain Maple	White Cedar- Black Spruce
Moisture regime:	Fresh	Moist	Wet
Depth of organic (cm):	10	20	40 - 200
Humus form:	Fibrihumimor	Raw Moder	Humic Peaty Mor
Texture:	Silty Clay Loam	Silty Clay	Organic

Fig. 12

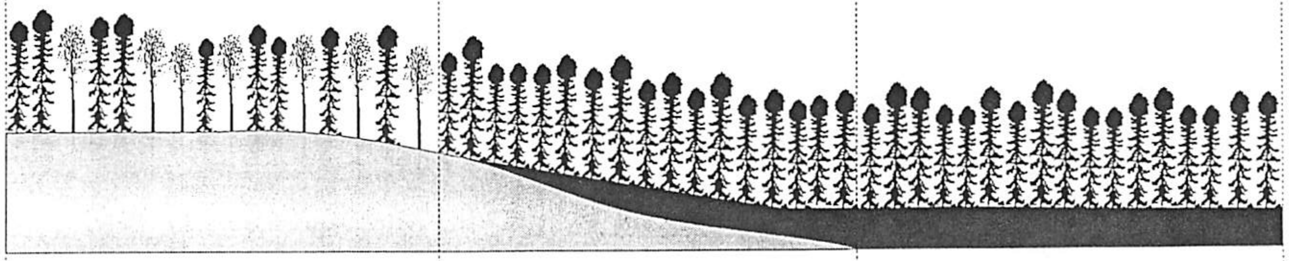
Conifer - Mixedwood Sequence on Fine Loamy to Clayey Soil



	Sb-Bf	Po-Sb-Bf-Sw	Sw-Bf-Sb	Sb-Ce-L
Site type:	5a	6a	9	13
Name:	Black Spruce-Fine Soil	Mixedwood-Fine Soil	Conifer-Moist Soil	Conifer-Speckled Alder
Vegetation type:	23	8	7	20
Name:	Black Spruce-Feathermoss-Sphagnum	Trembling Aspen-Black Spruce	White Spruce-Balsam Fir-White Cedar-Mountain Maple	White Cedar-Black Spruce
Moisture regime:	Fresh	Fresh	Moist	Wet
Depth of organic (cm):	10	10	25	40 - 100
Humus form:	Fibrimor	Fibrimor	Humic Peaty Mor	Humic Peaty Mor
Texture:	Silty Clay	Silty Clay	Silty Clay	Organic

Fig. 13

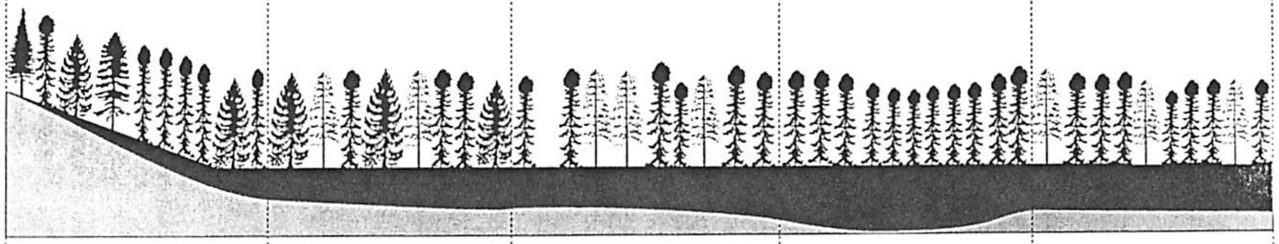
Black Spruce Sequence on Fine Loamy to Clayey Soil



	Sb-(Po)	Sb	Sb
Site type:	5a	8	11
Name:	Black Spruce-Fine Soil	Black Spruce-Feathermoss-Sphagnum	Black Spruce-Labrador-tea
Vegetation type:	22	23	25
Name:	Black Spruce-Feathermoss	Black Spruce-Feathermoss-Sphagnum	Black Spruce-Labrador-tea-Sphagnum
Moisture regime:	Fresh	Moist	Wet
Depth of organic (cm):	10	30	40-200
Humus form:	Fibrimor	Fibric Peaty Mor	Fibric Peaty Mor
Texture:	Silty Clay	Silty Clay	Organic

Fig. 14

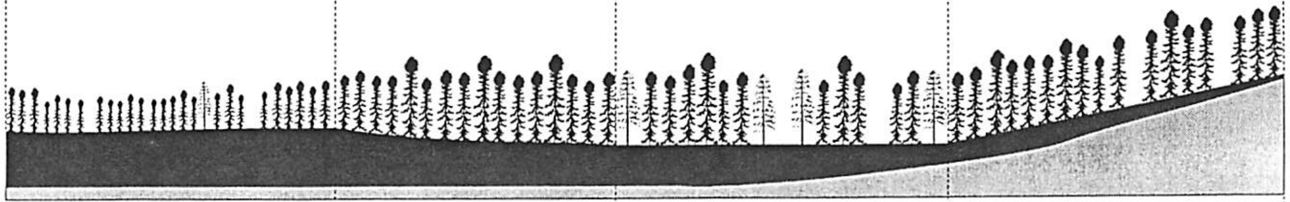
Conifer Sequence on Organic Soil



	Sb-Ce-Sw-Bf	Ce-L-Sb	Sb	Sb	Sb-L
Site type:	9	13	12	11	12
Name:	Conifer-Moist Soil	Conifer-Speckled Alder	Black Spruce-Speckled Alder	Black Spruce-Labrador-tea	Black Spruce-Speckled Alder
Vegetation type:	7	20	21	25	19
Name:	White Spruce-Balsam Fir-White Cedar-Mountain Maple	White Cedar-Black Spruce	Black Spruce-Speckled Alder-Sphagnum-Stair-step Moss	Black Spruce-Labrador-tea-Sphagnum	Black Spruce-Larch-Speckled Alder
Moisture regime:	Moist	Wet	Wet	Wet	Wet
Depth of organic (cm):	25	40 - 70	70 - 100	100 - 150	80 - 120
Humus form:	Humimor	Humic Peaty Mor	Mesic Peaty Mor	Fibric Peaty Mor	Fibric Peaty Mor
Texture:	Silt Loam	Organic	Organic	Organic	Organic

Fig. 15

Black Spruce Sequence on Organic Soil



	Sb (stunted)	Sb	Sb-L	Sb
Site type:	14	11	12	8
Name:	Black Spruce-Leatherleaf	Black Spruce-Labrador-tea	Black Spruce-Speckled Alder	Black Spruce-Feathermoss-Sphagnum
Vegetation type:	26	25	21	23
Name:	Black Spruce-Leatherleaf-Sphagnum	Black Spruce-Labrador-tea-Sphagnum	Black Spruce-Speckled Alder	Black Spruce-Feathermoss-Sphagnum
Moisture regime:	Wet	Wet	Wet	Moist
Depth of organic (cm):	150	80 - 150	40 - 80	25
Humus form:	Fibric Peaty Mor	Fibric Peaty Mor	Mesic Peaty Mor	Fibric Peaty Mor
Texture:	Organic	Organic	Organic	Silty Clay

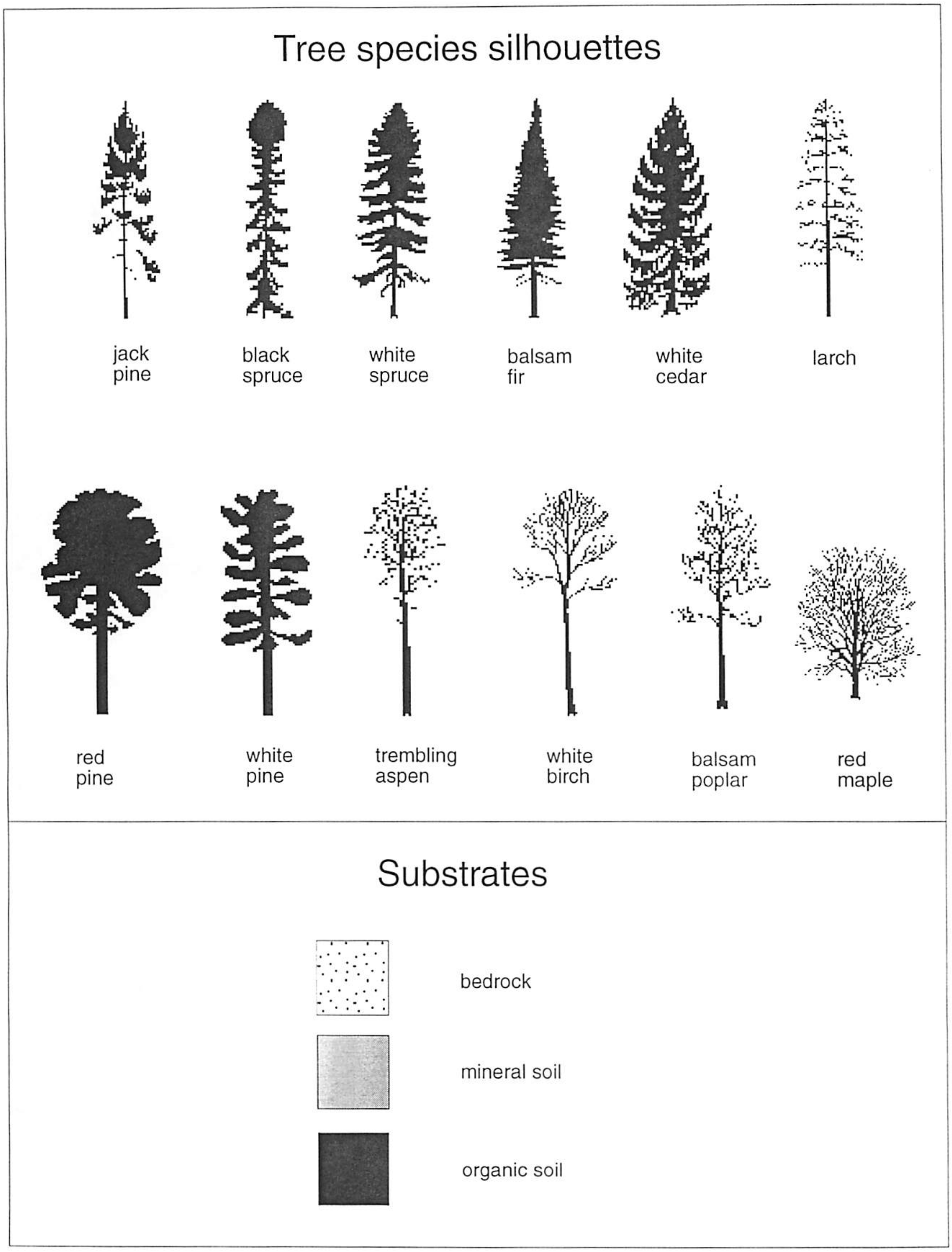


Figure 16. Key to tree species silhouettes and substrates used in the toposequence diagrams.

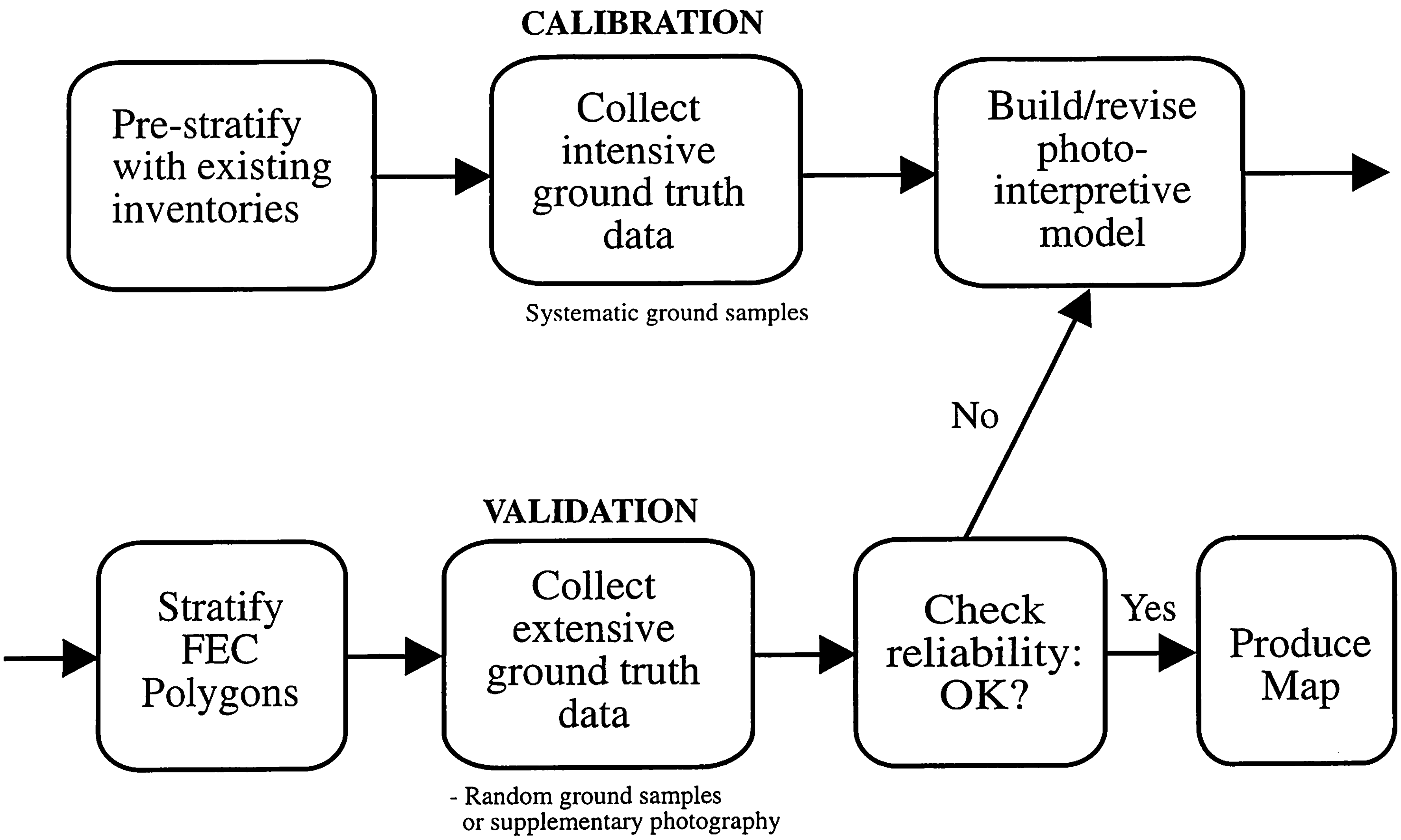
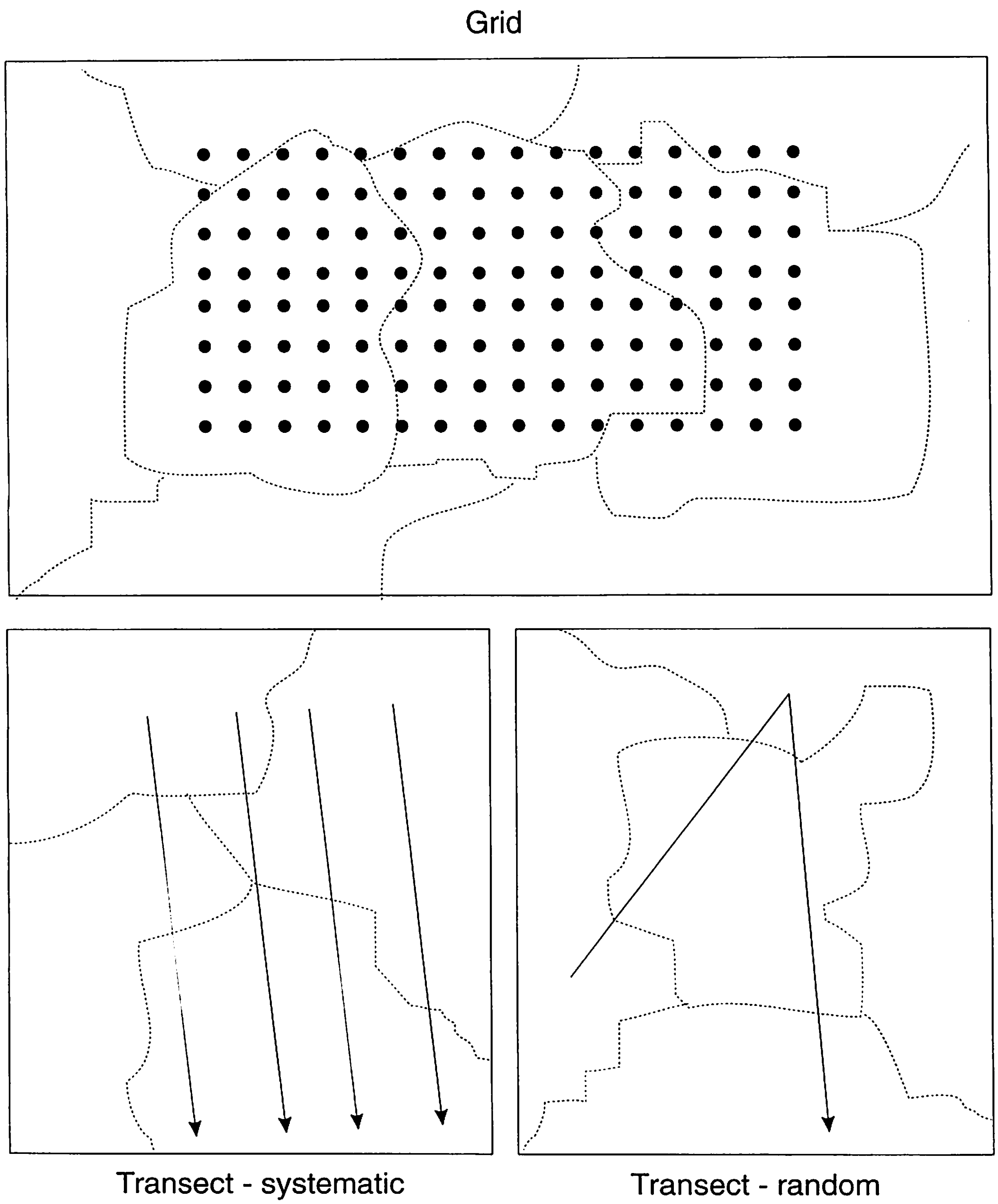


Figure 17. Flow chart showing the tasks involved in a forest ecosystem mapping project.



Grid

Transect - systematic

Transect - random

Figure 18. Examples of sampling methods for ground truthing.

Table 3. Frequency distribution for NE-FEC site types occurring adjacent to each other along linear transects, as a percentage of samples for each site type.

	Adjacent site type																						
Site type	1	2a	2b	3a	3b	4	5a	5b	6a	6b	6c	7a	7b	8	9	10	11	12	13	14	15	16	Sample size
1	70	0	0	1	4	0	0	1	0	2	7	0	0	0	5	2	1	1	2	0	0	0	204
2a	0	53	16	3	12	10	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	0	73
2b	0	6	80	1	4	4	0	0	1	0	0	1	0	0	1	1	0	1	1	0	0	0	170
3a	3	2	0	38	16	7	0	2	3	0	5	2	2	0	0	3	0	0	17	0	0	0	58
3b	7	4	4	4	43	7	0	1	2	2	12	1	1	1	3	2	1	2	2	0	1	0	161
4	0	6	5	4	10	32	3	3	1	1	0	1	0	5	13	3	1	4	8	1	0	0	79
5a	0	0	1	2	1	2	28	3	12	0	0	3	0	7	4	2	16	12	8	0	0	0	115
5b	3	0	0	3	5	5	10	33	0	5	0	0	0	5	10	0	5	8	8	0	0	0	39
6a	2	1	1	1	1	0	8	0	37	0	1	4	1	2	8	5	7	4	17	1	0	0	163
6b	5	0	0	6	0	0	0	0	5	47	6	0	11	0	3	2	2	0	13	2	0	0	64
6c	8	1	0	0	7	1	1	2	1	3	54	5	2	0	4	4	1	0	6	1	3	0	157
7a	0	0	0	1	0	0	1	0	3	1	2	69	3	0	2	11	1	1	4	0	0	0	291
7b	3	1	0	1	3	0	1	1	1	7	7	10	51	0	0	5	0	0	8	0	0	0	73
8	1	0	2	0	3	3	7	2	1	0	0	1	0	23	10	0	17	19	6	2	0	0	86
9	5	1	1	0	5	4	4	1	8	0	3	4	1	2	30	6	6	5	13	0	0	0	226
10	2	0	1	1	2	1	1	0	7	1	3	19	2	2	8	46	1	0	5	0	0	0	167
11	0	0	1	0	1	1	4	0	1	0	0	1	0	3	4	0	56	16	6	7	0	0	509
12	0	0	0	0	0	0	3	0	2	0	0	0	0	2	3	1	17	55	12	5	0	0	477
13	1	0	0	1	1	1	2	1	3	1	1	2	1	1	8	2	7	9	57	2	0	0	538
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	9	5	66	0	0	217
15	0	0	0	0	7	0	0	0	0	0	13	0	0	0	0	7	0	0	13	0	40	20	15
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	3

Table 4. Examples of NE-FEC site and vegetation type distributions in FRI stands, Kapuskasing study area.

Heterogeneous, black-spruce dominated mixedwood stand on undulating clay till, with spruce-fir forests (ST 6a) or black spruce-feathermoss forests (ST 5a) on ridges, interspersed with black spruce peatlands in drainageways (ST 12, 13) and in depressions (ST 11).

ST:	5a	5a	8	12	6a	6a	6a	11	6a	6a	13	6a	11
VT:	22	22	22	22	23	23	23	19	6	7	10	6	21

Homogeneous upland mixedwood stand on fresh clay till (ST 7a) with sandy to sandy loam soils on partially buried esker ridge (ST 6c, 7b). Stand could be subdivided on the basis of the two different landforms.

ST:	7a	7a	7a	7a	7a	7a	7a	7a	7a	7b	6c	7a	6c	7a	7a	6b	7b
VT:	6	7	7	7	7	7	9	9	9	7	11	7	12	12	7	8	7

Black spruce stand that could be subdivided into two spatially distinct types, black spruce-feathermoss (ST 5a) and black spruce-Labrador tea (ST 11). Note transitional site types at boundary.

ST:	11	11	11	11	3b	9	5a	5a	6a	5a	5a
VT:	25	25	25	22	22	22	21	21	7	14	22

Homogeneous upland mixedwood stand on clay till plain, with type change at boundary.

ST:	7a	7a	7a	7a	7a	5a
VT:	7	7	7	7	7	14

Mixedwood stand on undulating clay till, with repeating pattern of uplands on ridges (ST 7a) and peatlands in valleys (ST 13).

ST:	7a	7a	7a	7a	6a	13	13	7a	7a	7a	13	13	13	13
VT:	7	7	7	9	7	7	6	9	7	7	20	20	20	20

Upland mixedwood stand on convex hill in clay till plain, with consistent type changes at boundaries.

ST:	9	13	10	7a	7a	7a	7a	7a	7a	7a	7a	9	10
VT:	21	22	14	14	19	19	7	7	7	7	7	14	14

Poor black spruce peatland in depression (ST 14) with consistent type changes at boundaries: black spruce-alder stands at lagg areas (ST 12), adjacent to rich peatlands near drainageways (ST 13).

ST:	13	12	11	14	14	12	14	14	12	12	13
VT:	20	20	19	19	26	25	26	26	19	20	20

Table 5. Examples of NE-FEC site and vegetation type distribution in FRI Stands, Timmins study area.

Homogeneous upland mixedwood stand on medium sand, with type change at boundary.

ST:	6c	6c	6c	6c	6c	6c	3b
VT:	12	12	12	12	12	12	13

Homogeneous jack pine stand on sand, varying from fine to coarse, with transition to mixedwood stand at boundary.

ST:	2a	2b	2a	2b	2a	2a	2a	2a	4	2b	2b	2b	2b	2b	2b	3b	3b
VT:	16	16	16	16	18	18	16	16	18	18	18	18	18	16	18	13	13

Heterogeneous mixedwood stand on loamy till, with undulating topography, aspen or spruce-dominated stands on ridges and moist to wet drainageways in valleys.

ST:	5b	13	6b	6b	9	5b	9	6c	6c	6c	3b	6c	9
VT:	23	22	14	14	14	18	24	12	14	14	14	12	12

Heterogeneous mixedwood stand on fine outwash, comprised mainly of fresh aspen-jack pine upland forest (ST 3b) interspersed with moist black spruce-jack pine forest (ST 4, 9) in intermittent drainageways.

ST:	9	9	4	2a	4	4	3b	3b	3b	3b	3b	3b	4	3b	3b	3b	3b	4	3b	2b	3b	5b	3b	3b	9	5b
VT:	20	23	23	23	23	23	14	23	13	14	14	14	14	14	14	14	14	23	14	16	14	14	14	14	23	23

Stand that could be subdivided into three spatially distinct site type conditions.

ST:	6b	6b	13	13	13	13	13	13	13	11	14	11	11	11
VT:	13	6	14	20	20	14	14	14	20	22	25	25	25	25

Very homogeneous, rich peatland forest.

ST:	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
VT:	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20

Heterogeneous peatland forest on slightly undulating till material, with rich telluric forests (ST 9, 13) in drainageways, and poor black spruce peatlands (ST 8, 11) on deeper peats in depressions.

ST:	11	11	4	9	9	9	13	13	13	9	9	8	8	12	11	4	8
VT:	25	25	23	14	23	14	21	6	22	23	23	24	23	26	23	23	23

Table 6. Common site type associations based on frequency of adjacent positions along linear transects.

	Associated site types		
Site type	Uplands	Moist Transitions	Wetlands
1	various	9	none
2a	2b, 3b, 4	none	none
2b	2a	none	none
3a	3b, 4	10	13
3b	6c, 4	9, 10	none
4	3b, 2a	9, 8	13
5a	6a	8, 9	11, 12, 13
5b	5a	9, 8	12, 13, 11
6a	5a	9, 10	13, 11
6b	7b, 6c	9, 10	13
6c	3b, 1	9, 10	13
7a	none	10	none
7b	7a, 6c, 6b	10	13
15	16, 6c, 3b	10	13
16	15	na	na
8	9, 5a	na	12, 11
9	6a, various	na	13
10	9, 7a, 6a	na	13
11	12, 14	9, 8	na
12	11, 13	9, 8	na
13	12, 11	9	na
14	11, 12	none	na

Table 7. Reliability test scores for air photo interpretation of NE-FEC site types: percent of polygons interpreted correctly when compared with ground truth samples.

Test criteria	Percentage of polygons
Timmins Study Area	
All test polygons	73.0
Test polygons with 4 or more ground truth samples	84.7
Group ST 9, 13; 8, 11; 2a, 2b; and 3b, 6c into complexes	82.0
Polygons with 4+ samples; and grouping ST's into complexes	88.1
Kapuskasing Study Area	
All test polygons	66.3
Test polygons with 4 or more ground truth samples	74.8
Group ST 3a, 3b; 7a, 7b, 6c, 10; 5a, 5b, 8; and 12, 13 into complexes	79.2
Polygons with 4+ samples; and grouping ST's into complexes	87.9

Table 8. Photo interpretation reliability by NE-FEC site type (compared with ground truth samples), and common interpretation errors.

Predicted site type	Sample size	Percentage of polygons correctly interpreted	Common errors
1	11	82	na
2a	8	75	2b
2b	1	100	na
3a	3	67	7a
3b	20	73	3a
4	9	57	2a
5a	2	50	8
5b	7	60	9
6a	16	75	7a, 7b, 6c
6b	5	60	6c, 9
6c	7	86	10
7a	43	74	7b, 6a
7b	2	50	6c
8	4	50	9
9	31	74	13
10	6	83	7a, 9
11	21	76	8, 12
12	22	68	13
13	51	86	9, 12
14	18	94	11
15	1	100	na

Table 9. Degree of error for NE-FEC site types. The degree of error provides an estimate of the errors significance to the making of forest management decisions, when contrasting the predicted map polygon site type to the ground observation site type.

Observed	Predicted Site Type																				
Site Type	1	2a	2b	3a	3b	4	5a	5b	6a	6b	6c	7a	7b	8	9	10	11	12	13	14	15	16
1	x	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
2a		x	1	2	2	1	2	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3
2b			x	2	2	1	2	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3
3a				x	1	2	2	2	2	1	1	3	2	3	3	3	3	3	3	3	3	3
3b					x	2	2	2	3	2	1	3	1	3	3	3	3	3	3	3	3	3
4						x	2	1	3	2	3	3	3	2	3	3	3	3	3	3	3	3
5a							x	1	2	3	3	3	3	2	2	3	3	3	3	3	3	3
5b								x	2	2	3	3	3	2	2	3	3	3	3	3	3	3
6a									x	2	2	2	2	3	3	3	3	3	3	3	3	3
6b										x	1	3	2	3	3	3	3	3	3	3	2	3
6c											x	3	2	3	3	2	3	3	3	3	2	3
7a												x	2	3	2	2	3	3	3	3	2	3
7b													x	3	2	2	3	3	3	3	2	3
8														x	2	2	2	2	3	3	3	3
9															x	2	3	2	2	3	3	3
10																x	3	3	3	3	2	3
11																	x	2	3	2	3	3
12																		x	2	2	3	3
13																			x	3	3	3
14																				x	3	3
15																					x	2
16																						x

Degree of error: 1 = low; 2 = medium; 3 = high.

Table 10. Comparison of numbers and sizes of NE-FEC polygons with FRI stands for two test OBM sheets.

	Study Area	
Parameter	Timmins	Kapuskasing
OBM mapsheet	49-533	42-549
Area mapped (ha)	8002	8397
Other area * (ha)	1998	1603
No. FRI stands	462	226
Mean FRI stand area (ha)	17.3	37.2
No. FEC polygons	843	437
Mean FEC polygon area (ha)	9.5	19.2
FRI/FEC Ratio	1.8	1.9

* other area includes water, non-productive forest, and recent cutovers.

Table 11. Predicted relationship between NOEGTS terrain unit types and surface soil texture classes comprising groups of NE-FEC site types.

Texture Class	Dominant Site Types	NOEGTS Legend Symbols					
		Mode of deposition		Landform		Material	
Sandy to Coarse Loamy	ST 2a, 2b, 3b, 4, 6c	M	moraine	ME	end	s, t, ts	sand, till, sandy till
				MH	hummocky		
				MG	ground		
		G	glaciofluvial	GD	delta	s, g, sg	sand, gravel, gravelly sand
				GE	esker		
				GK	kame		
				GO	outwash		
		L	(glacio)lacustrine	LB	beach	s	sand
				LD	delta		
				LP	plain		
		A	alluvial	AP	plain	s	sand
		E	eolian	ED	dunes	s	sand
Medium Loamy to Silty	ST 3a, 5b, 6b, 7b	M	moraine	MH	hummocky	tm	silty till
				MG	ground		
		G	glaciofluvial	GD	delta	m	silt
				GO	outwash		
		L	(glacio)lacustrine	LD	delta	m	silt
				LP	plain		
		A	alluvial	AP	plain	m	silt
Fine Loamy to Clayey	ST 5a, 6a, 7a	M	moraine	MH	hummocky	tc	clayey till
				MG	ground		
		L	(glacio)lacustrine	LD	delta	c, cm	clay, silty clay
				LP	plain		
Organic	ST 11, 12, 13, 14	O	organic	OT	organic	p	peaty
Bedrock, bedrock-controlled soils, rock	ST 1; other ST's depends on subordinate landform and material	R	rock	RL	plateau	na	bedrock
				RN	knob		
				RP	plain		
				RR	ridge		
				/R	underlain by rock		
		C	colluvium	CS	slope failure		
				CT	talus pile		
				CW	slopewash and debris creep sheet		

Table 12. Predicted relationship between soil series mapped by Canada Land Inventory (Ontario Soil Survey) program and NE-FEC site types.

Map Symbol	Soil Name	Soil Material	Drainage	Dominant ST's	Associated ST's
Bedrock					
R	Rock	acidic precambrian rock		1	
T	Timiskaming	rock outcrop with lacustrine varved clay	good to poor	1	6a, 9, 10
Dry to Fresh Sandy Glaciofluvial Material					
Abs, Absl, ABl, Abgsl	Abitibi	acidic medium sand outwash	well	2a, 2b, 3b, 6c	4, 8, 9
Brsl	Black River	very fine sand outwash	moderately well		
Jnsl, Jns, Jngs, Jngsl, Jngl	Jeannie	acidic medium to coarse sandy gravel	well		
Mys, Mysl, Myvfs	Mary	acidic fine sand outwash	well		
Wds	Wendigo	acidic sand	well		
Moist Sandy Glaciofluvial Material					
Ans, Ansl	Ansonville	acidic fine sand outwash	imperfect	4, 8, 9	3b, 6c
Frs, Frsl	Frederick	acidic medium sand outwash	poor		
Gas, Gasl	Gaffney	acidic fine sand outwash	poor		
Ms	Mallard	stratified acidic sand	imperfect		
Pys, Pysl, Pygsl	Pyne	acidic medium sand	imperfect		
Wns, Wnsl	Withington	acidic fine sand outwash	imperfect		
Fresh Coarse Loamy Till Material					
Hns, Hnsl, Hnl	Hanna	acidic medium to coarse sandy till	well	3b, 5b, 6b, 7b	8, 9, 10
Wos, Wosl	Woolley	very fine sand outwash	well		
Moist Coarse Loamy Till Material					
Ens, Ensl	English	acidic medium to coarse sandy till	poor	8, 9, 10	3b, 5b, 6b, 7b
Kasl, Kal	Keenoa	very fine sand outwash	poor		
Mksl	Makobe	acidic medium to coarse sand till	imperfect		
Nsl	Newfeld	very fine sand	moderately poor		
Fresh Silty Till or Lacustrine Material					
Apsil	Alpine	silt over calcareous clay to silty clay	moderately well	5b, 6b, 7b	5a, 6a, 7a 8, 9, 10
Esil	Ecclestone	lacustrine silt loam	moderately well		
Ksil	Kapuskasing	silt over calcareous clay to silty clay	moderately well		
Moist Silty Till or Lacustrine Material					
Bsil, Bcl, Bl	Biz	calcareous lacustrine silt loam	poor	8, 9, 10	5a, 6a, 7a
Pesil	Pense	lacustrine silt loam or silty clay loam	imperfect		
Psil	Porquis	silt over calcareous clay to silty clay	imperfect		
Sisil	Siamese	silt over calcareous clay to silty clay	poor		
Tusil	Tunis	silt over calcareous clay to silty clay	moderately poor		
Fresh Fine Loamy Till or Clayey Lacustrine Material					
Ccl, Cc, Cl, Csil	Clegg	calcareous lacustrine clay to silty clay	moderately well	5a, 6a, 7a	8, 9, 10
Decl, Del	Delray	calcareous lacustine clay to silty clay	well		
Hac	Haileybury	lacustrine calcareous clay	well		
Locl, Loc	Lowther	calcareous clay loam till	moderately well		
Vcl, Vccl, Vcc	Val Cote	silt loam to silty clay loam calcareous till	well		
Moist Fine Loamy Till or Clayey Lacustrine Material					
Acl, Al, Asil	Audrey	silt loam to silty clay loam calcareous till	moderately poor	8, 9, 10	5a, 6a, 7a
Dtcl, Dtc, Dtl, Dtsil	Devitt	silt loam to silty clay loam calcareous till	imperfect		
Focl, Fol	Ford	silt loam to silty clay loam calcareous till	poor		
Hecl, Hec, Hel, Hesil	Hearst	calcareous lacustrine clay to silty clay	imperfect		
Rycl, Ryc, Rysil, Ryl	Ryland	calcareous lacustrine clay to silty clay	moderately poor		
Shcl, Shl, Shc, Shsil	Shetland	calcareous lacustrine clay to silty clay	poor		

Table 12. Predicted relationship between soil series mapped by Canada Land Inventory (Ontario Soil Survey) program and NE-FEC site types (continued).

Map Symbol	Soil Name	Soil Material	Drainage	Dominant ST's	Associated ST's
Organic Materials					
Humic					
Kg	Kenogami	humic organic over mineral soil	poor	13	12, 11, 9
Ld	Larder	deep humic organic	poor		
Sk	Sesekinika	deep mesic over humic organic	poor		
We	Wade	humic organic over mineral soil	poor		
Ww	Wistiwasing	deep humic organic	poor		
Mesic					
Bv	Belle Vallee	mesic organic over mineral soil	poor	13, 12	11, 9, 8
Le	Leeville	deep mesic organic material	poor		
Sas	Sasaginaga	deep fibric over mesic organic	poor		
Sn	Sunstrum	mesic organic over mineral soil	poor		
U	Uno Park	mesic organic over mineral soil	poor		
Fibric					
Gf	Gaffney Lake	deep fibric organic	poor	11, 14	12, 13, 9, 8
Hy	Harley	deep fibric over mesic organic	poor		
Ku	Kushog	fibric organic over mineral soil	poor		
Ng	Norembega	deep fibric organic	poor		
Tom	Tomstown	deep fibric organic	poor		

Table 13. Occurrence (percent of sample plots) of tree species in NE-FEC site types.

Site	Sample	Hardwoods								Conifers							
Type	size	Ab	Bw	By	Elm	Pb	Pt	Mh	Ms	Bf	Ce	L	Pj	Pr	Pw	Sb	Sw
1	20	0	10	0	0	0	15	0	0	5	0	5	45	0	5	60	20
2a	21	0	0	0	0	0	10	0	0	0	0	0	95	0	0	24	0
2b	23	0	4	0	0	0	0	0	0	4	0	0	91	4	0	35	0
3a	13	0	0	0	0	8	62	0	0	15	0	0	54	0	0	31	8
3b	70	0	16	0	0	1	63	0	0	6	0	0	59	4	1	29	20
4	32	0	0	0	0	0	9	0	0	9	0	0	72	0	0	66	0
5a	14	0	0	0	0	0	14	0	0	7	0	7	36	0	0	86	0
5b	10	0	0	0	0	0	0	0	0	0	0	0	70	0	0	70	0
6a	28	0	14	0	0	32	61	0	0	14	4	0	18	0	0	46	11
6b	19	0	21	0	0	21	58	0	0	37	0	0	53	0	5	26	26
6c	47	0	26	0	0	0	68	0	0	13	9	0	28	4	4	15	30
7a	37	0	5	0	0	22	76	0	0	11	3	0	5	0	0	11	24
7b	31	0	16	0	0	6	84	0	0	13	6	0	10	3	3	6	26
8	30	0	3	0	0	0	10	0	0	0	0	3	13	0	0	100	0
9	46	0	13	0	0	0	7	0	0	24	11	22	13	0	0	74	43
10	41	2	12	0	2	41	88	0	0	12	0	0	5	0	0	15	7
11	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91	0
12	30	0	0	0	0	0	0	0	0	3	3	10	0	0	0	100	0
13	37	3	3	0	0	0	0	0	0	5	16	24	0	0	0	86	8
14	11	0	0	0	0	0	0	0	0	0	0	9	0	0	0	64	0
15	12	0	58	0	0	0	50	0	50	33	0	0	0	0	0	8	42
16	12	0	25	58	0	0	42	42	0	0	0	0	0	0	0	0	17

Tree Species: Ab = black ash, Bw = white birch, By = yellow birch, E = white elm, Pb = balsam poplar, Pt = trembling aspen, Mh = sugar maple, Ms = red maple, Bf = balsam fir, Ce = eastern white cedar, L = larch, Pj = jack pine, Pr = red pine, Pw = eastern white pine, Sb = black spruce, Sw = white spruce.

Table 14. Occurrence (percent of sample plots) of tree species in NE-FEC vegetation types.

Vegetation	Sample	Hardwoods								Conifers							
type	size	Ab	Bw	By	Elm	Pb	Pt	Ms	Mh	Bf	Ce	L	Pj	Pr	Pw	Sb	Sw
V1	2	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0
V2	10	0	30	100	0	0	50	0	30	0	0	0	0	0	0	0	20
V3	13	0	54	0	0	0	46	100	0	31	0	0	0	0	0	8	46
V4	4	0	75	0	0	0	50	0	0	25	0	0	25	0	100	0	0
V5	7	0	0	0	0	0	57	0	0	0	0	0	43	100	29	14	14
V6	19	0	0	0	0	0	11	0	0	16	5	5	5	0	0	100	26
V7	33	3	21	0	0	0	3	0	0	30	36	6	3	0	0	33	73
V8	28	0	4	0	0	36	79	0	0	7	0	0	29	0	0	36	7
V9	45	0	18	0	0	24	87	0	0	27	0	0	2	0	0	4	24
V10	28	4	4	0	4	64	79	0	0	7	0	0	7	0	0	7	7
V11	20	0	10	0	0	0	95	0	0	5	5	0	5	0	0	0	20
V12	44	0	20	0	0	0	77	0	0	14	2	0	41	0	0	5	23
V13	63	0	14	0	0	3	73	0	0	6	0	0	48	0	0	33	8
V14	31	0	35	0	0	0	32	0	0	26	0	3	45	0	0	65	61
V15	23	0	4	0	0	0	9	0	0	0	0	0	96	0	0	0	0
V16	23	0	0	0	0	0	0	0	0	0	0	4	87	0	0	65	0
V17	16	0	0	0	0	0	0	0	0	0	0	0	100	0	0	6	0
V18	29	0	3	0	0	3	14	0	0	7	0	0	76	0	0	72	0
V19	15	0	0	0	0	0	0	0	0	0	0	93	7	0	0	93	0
V20	11	0	0	0	0	0	0	0	0	9	45	0	0	0	0	82	0
V21	28	0	0	0	0	0	0	0	0	4	0	0	0	0	0	100	0
V22	22	0	0	0	0	0	14	0	0	0	0	0	23	0	0	91	0
V23	48	0	0	0	0	0	13	0	0	6	0	6	25	0	0	92	0
V24	26	0	4	0	0	0	0	0	0	0	0	12	0	0	0	100	0
V25	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	89	0
V26	10	0	0	0	0	0	0	0	0	0	0	10	0	0	0	60	0

Tree Species: Ab = black ash, Bw = white birch, By = yellow birch, E = white elm, Pb = balsam poplar, Pt = trembling aspen, Mh = sugar maple, Ms = red maple, Bf = balsam fir, Ce = eastern white cedar, L = larch, Pj = jack pine, Pr = red pine, Pw = eastern white pine, Sb = black spruce, Sw = white spruce.

Table 15. Strategy for assigning FRI stands to one of 17 vegetation/site type complexes using FRI attributes (algorithm #1).

Sort Order	Complex Number	Vegetation Type	Description	Site Type	FRI Sort Criteria *	OR
1	1	V1	Sugar Maple	ST 16	MS + MH + BY + OH >= 5	MS + MH + BY >= 3
		V2	Yellow Birch Mixedwood	ST 16		
		V3	Red Maple Mixedwood	ST 15		
2	2	V4	White Pine Mixedwood	ST 1 ST 6b	PW >= 2	
3	3	V5	Red Pine Mixedwood	ST 2b ST 3b	PR >= 2	
4	5	V7	White Spruce - Balsam Fir - Mountain Maple	ST 9	SW + CE >= 4 AND SW >= 3	
5	14	V20	White Cedar - Black Spruce	ST 9 ST 13	CE >= 3	
6	13	V19	Black Spruce - Larch - Speckled Alder	ST 13	LA + OC >= 3	
7	17	V26	Black Spruce - Leatherleaf - Sphagnum	ST 14	WG = SB AND SC = 4	WG = SB AND SC = 3 AND STK <= 0.5
8	16	V22	Black Spruce - Feathermoss	ST 11 ST 8	WG = SB AND SC = 3 AND STK >= 0.6	
		V24	Black Spruce - Speckled Alder - Sphagnum - Schreber's Moss	ST 11 ST 12 ST 8		
		V25	Black Spruce - Labrador-tea - Sphagnum	ST 11		
9	7	V10	Balsam Poplar - Trembling Aspen - Speckled Alder	ST 10	WG = P0 AND PB + A >= 3	
10	6	V8	Trembling Aspen - Black Spruce	ST 6a ST 6b	WG = PO AND PJ >= 1 AND WG = BF	WG = PJ AND PO + BW >= 1
		V12	Trembling Aspen Mixedwood	ST 6c ST 3a		
		V13	Trembling Aspen - Black Spruce - Blueberry	ST 3b		
11	8	V9	Trembling Aspen - Balsam Fir - Mountain Maple	ST 7a	WG = PO AND PJ = 0	
		V11	Trembling Aspen - Mountain Maple - Beaked Hazel	ST 7b		
12	9	V14	White Spruce - White Birch - Feathermoss	ST 3a ST 3b	WG =PO AND BW + SW >= 3	

Table 15. Strategy for assigning FRI stands to one of 17 vegetation/site type complexes using FRI attributes (ocntinued).

Sort Order	Complex Number	Vegetation Type	Description	Site Type	FRI Sort Criteria *	OR
13	10	V15	Jack Pine - Blueberry - Feathermoss	ST 2a ST 2b	WG = PJ AND PJ >= 9	
		V17	Jack Pine - Black Spruce - Labrador-tea	ST 3b		
14	11	V16	Jack Pine - Black Spruce - Feathermoss	ST 2b ST 2a	WG = PJ AND SB + PJ >= 7 AND PO <= 1	
15	12	V18	Black Spruce - Jack Pine - Feathermoss	ST 4 ST 5b	WG = SB AND PO + PJ >= 2 AND OC + CE + LA = 0	
		V23	Black Spruce - Feathermoss - Sphagnum	ST 5a ST 4 ST 8		
16	4	V6	Black Spruce - Speckled Alder - Feathermoss	ST 13	WG = SB AND SW + BF >= 1	
17	15	V21	Black Spruce - Speckled Alder - Sphagnum - Stair-step Moss	ST 12	WG = SB AND SW + BF = 0	
18	14	V20	White Cedar - Black Spruce	ST 9 ST 13	WG = SB AND CE + L + OC >= 1	

* WG = working group; SC = site class; STK = stocking class.

* A = black ash; BF = balsam fir; BW = white birch; BY = yellow birch; CE = white cedar; LA = larch; MH = sugar maple; MS = red maple; OC = other conifer; OH = other hardwood; PB = balsam poplar; PJ = jack pine; PO = poplar; PR = red pine; PW = white pine; SB = black spruce; SW = white spruce.

Table 16. Strategy for assigning FRI stands to one of 11 site type complexes using FRI attributes (algorithm #2).

Sort Order	FRI sort criteria *	Complex number	Site types	Description
1	SC =4 AND WG = SB, L, OC	11	14	Black Spruce - Leatherleaf
2	SC = 4 AND WG <>SB, L, OC	1	1	Very shallow soil
3	PJ > 6 AND SB > 2	4	4	Jack Pine - Black Spruce - coarse soil
4	PJ > 6 AND SB < 3	2	2a, 2b	Jack Pine - sandy soil
5	CE > 5	8	13	Cedar - Speckled Alder
6	SB > 6 AND PJ > 1	2	2a, 2b	Jack Pine - sandy soil
7	SB > 6 AND SC = 2, 3 AND SB = 10	10	11	Black Spruce - Labrador-tea
8	SB > 6 AND SC = 2, 3 AND SB < 10	9	12, 13	Conifer - Speckled Alder
9	SB > 6 AND SC = X, 1 AND SB = 10	9	12, 13	Conifer - Speckled Alder
10	SB > 6 AND SC = X, 1 AND SB < 10	5	5a, 5b, 8, 9	Conifer - Feathermoss - Sphagnum
11	WG = PO AND PJ = 0	7	7a, 7b, 10, 6c	Hardwood
12	WG = PO AND PJ > 0	3	3a, 3b	Mixedwood - coarse to medium soil
13	WG = PJ AND SC = X, 1, 2	3	3a, 3b	Mixedwood - coarse to medium soil
14	WG = PJ AND SC = 3	7	7a, 7b, 10, 6c	Hardwood
15	WG = SB AND PJ + SB > 8	4	4	Jack Pine - Black Spruce - coarse soil
16	WG = SB AND SC = X, 1	6	6a, 6b	Conifer Mixedwood - medium to fine soil

Table 16. Strategy for assigning FRI stands to one of 11 site type complexes using FRI attributes (continued).

Sort Order	FRI sort criteria *	Complex number	Site types	Description
17	WG = SB AND SC = 2, 3 AND CE + L + OC > 0	9	12, 13	Conifer - Speckled Alder
18	WG = SB AND PO + BW > 3	7	7a, 7b, 10, 6c	Hardwood
19	WG = SB AND PO + BW < 4	5	5a, 5b, 8, 9	Conifer - Feathermoss - Sphagnum
20	WG = SW AND PO > 0	7	7a, 7b, 10, 6c	Hardwood
21	WG = SW AND PO = 0	6	6a, 6b	Conifer Mixedwood - medium to fine soil
22	WG = BF	6	6a, 6b	Conifer Mixedwood - medium to fine soil
23	WG = BW	3	3a, 3b	Mixedwood - coarse to medium soil

* WG = working group; SC = site class.

* A = black ash; BF = balsam fir; BW = white birch; BY = yellow birch; CE = white cedar; LA = larch; MH = sugar maple; MS = red maple; OC = other conifer; OH = other hardwood; PB = balsam poplar; PJ = jack pine; PO = poplar; PR = red pine; PW = white pine; SB = black spruce; SW = white spruce.

Table 17. Test results for NE-FEC vegetation/site type complex predictive algorithm #1 using FRI attributes.

				No. stands matching:			Percent matching:	
Complex	VT's	ST's	No. Stands	Dominant ST	Subdom. ST	Either Dom. or Sub. ST	Dominant ST	Either Dom. or Sub. ST
1	1,2,3	15,16	1	0	0	0	0	0
2	4	1,6b	0	0	0	0	na	na
3	5	2b,3b	0	0	0	0	na	na
4	6	13	51	4	4	8	8	16
5	7	9	0	0	0	0	na	na
6	8,12,13	6abc,3ab	28	13	7	20	46	71
7	10	10	7	3	2	5	43	71
8	9,11	7ab	36	15	6	21	42	58
9	14	3ab	25	5	3	8	20	32
10	15,17	2ab,3b	12	8	0	8	67	67
11	16	2ab	22	15	2	17	68	77
12	18,23	4,5ab,8	25	3	3	6	12	24
13	19	13	5	0	0	0	0	0
14	20	9,13	26	16	6	22	62	85
15	21	12	72	20	15	35	28	49
16	22,24,25	8,11	19	7	5	12	37	63
17	26	14	41	11	4	15	27	37
All			370	120	57	177	32	48

Table 18. Test results for NE-FEC site type complex predictive algorithm #2 using FRI attributes.

			No. stands matching:			Percent matching:	
Complex	Site types	No. Stands	Dominant ST	Subdom. ST	Either Dom. or Sub. ST	Dominant ST	Either Dom. or Sub. ST
1	1	0	0	0	0	na	0
2	2a,b	24	15	1	16	63	67
3	3a,b	52	12	7	19	23	37
4	4	7	0	1	1	0	14
5	5a,b,8,9	35	6	8	14	17	40
6	6a,b	16	2	0	2	13	13
7	6c,7a,7b,10	46	28	8	36	61	78
8	11	63	23	16	39	37	62
9	12,13	98	42	17	59	43	60
10	13	4	3	1	4	75	100
11	14	25	13	3	16	52	64
All		370	144	62	206	39	56

Table 19. Percent of ground truth samples accounted for by annotating FRI stands with one to four site types.

No. Site types	Study Area			
Annotated	Iroquois Falls	Timmins	Kapuskasing	All
1	65.4	49.4	46.5	55.1
2	85.7	71.6	67.9	76.2
3	92.8	83.7	80.9	86.6
4	96.3	90.0	87.8	91.8
Total number of samples				2944

Table 20. Proportion of samples accounted for by annotating FRI stands with one (dominant) site type or two (dominant + subdominant) site types, summarized by NE-FEC site type.

Dominant Site type	No. of Stands	Proportion of FEC samples accounted for with: 1 ST	2 ST's
1	23	0.64	0.85
2a	2	0.57	0.80
2b	13	0.77	0.93
3a	4	0.45	0.65
3b	13	0.56	0.81
4	4	0.47	0.71
5a	2	0.37	0.70
5b	2	0.54	0.83
6a	15	0.47	0.75
6b	3	0.53	0.66
6c	10	0.51	0.73
7a	17	0.64	0.81
7b	5	0.59	0.76
8	3	0.48	0.63
9	8	0.36	0.59
10	9	0.69	0.90
11	25	0.56	0.80
12	30	0.69	0.88
13	46	0.52	0.75
14	16	0.61	0.83
15	1	0.47	0.74
All	251	0.56	0.77

Table 21. Approximate level of effort required for different NE-FEC mapping methods, expected mapping outputs, and map reliability levels.

	Tasks and person-day allocations *					
Mapping method	Inventory data handling	Air photo interpretation	Ground truthing	Total effort	Approximate reliability level	Result
Predictive map overlays	1	0	0	1	30 - 50%	Existing inventory polygons annotated with site type complexes of 3 to 4 ST's
Annotate existing map polygons (e.g., FRI stands)	1	2	0	3	75%	Existing inventory polygons annotated with 2 to 4 site types
Produce new FEC map base with minimal ground truthing	1	5	5	11	75 - 85%	Site type inventory; 50% individual site types; 50% site type complexes
Produce new FEC map base with intensive ground truthing	1	6	10	17	85 - 90%	Site type inventory; 80% individual site types; 20% site type complexes

* Time allocations are based on mapping an area equivalent to one OBM base map (100 km^2).