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An ecological framework to support the use of herbicide alternatives in boreal and northern temperate forests of Ontario and Quebec

First approximation

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Information Report
FI-X-025
2023

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Cat. no: Fo4-214/1-2023E-PDF
ISBN: 978-0-660-48290-3

Natural Resources Canada
Canadian Forest Service
580 Booth Street
Ottawa, ON K1A 0E4

A pdf version of this publication is available through the Canadian Forest Service Publications database: http://cfs.nrcan.gc.ca/publications.

Cet ouvrage est publié en français sous le titre : *Un cadre écologique pour soutenir l'utilisation de solutions de rechange aux herbicides dans les forêts boréales et tempérées septentrionales de l'Ontario et du Québec Première approximation*

TTY: 613-996-4397 (Teletype for the deaf)

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Abstract

We present an ecological framework for classifying sites to support vegetation management decisions in the boreal and northern temperate forests of northeastern Ontario and northwestern Quebec. This first approximation draws on several regional ecological classifications to provide an initial framework and background information for the Herbicide Alternatives Program (HAP) 2.0 in northeastern Ontario. It provides broad, ecologically and silviculturally meaningful overstory and understory classes based on dominant tree species and groups of understory plant species indicative of site moisture and nutrient conditions. These classes are intended to be applied at the plot or stand-level, during ground-based, pre-harvest assessments. The framework is currently being used to retrospectively classify the ecological conditions of study sites in a compendium of longer-term vegetation management studies so that we can relate treatment response to site conditions. As with various adaptive management approaches, we view the framework from an evolving perspective. As HAP 2.0 partners use the framework, refinements are likely to be made.

Introduction

Site classification is integral to sustainable ecosystem management and forestry. "Anything done in silviculture should be based on knowledge of the total environment of the site or habitat where trees and other organisms subsist and interact" (Smith et al., 1997). Over time and depending on scale and context, various ecosystem classification approaches have been used (e.g., bioclimatic [Halliday, 1937; Rowe, 1972; Baldwin et al., 2021], indicator species [Cajander, 1926], habitat type [Daubenmire and Daubenmire, 1968], soil-site [Soil Classification Working Group, 1998], and physiographic [Hills, 1952], among others [Ponomarenko and Alvo, 2001]). In Canada, ecologists began developing Forest Ecosystem Classification schemes to describe stand-level forest ecosystems in the 1950s and 1960s to address the complex climate-vegetation-environment characteristics of Canada's natural forest ecosystems (e.g., Dansereau, 1959; Damman, 1964; Krajina, 1965).

In Ontario, Forest Ecosystem Classification (FEC) development began in the 1980s and proceeded by administrative region (Sims and Uhlig, 1992; Ponomarenko and Alvo, 2001). Ontario's FECs largely consist of Vegetation Types and Soil Types (together referred to as Ecoelements) that describe recurring, ground-based patterns of vegetation communities and substrate conditions, and Ecosites, the province's finest-scale spatial unit of ecological landscape delineation. One or multiple combinations of Vegetation Type(s) and Soil Type(s) can describe conditions within a particular, or multiple Ecosites. Various versions of FECs have been developed independently for different regions of Ontario (Jones et al., 1983; Sims et al., 1989; Racey et al., 1989; McCarthy et al., 1994; Racey et al., 1996; Chambers et al., 1997; Sims et al., 1997; Lee et al., 1998; Taylor et al., 2000). More recently the Ontario Ministry of Natural Resources and Forestry has developed draft provincial Vegetation Types and Ecosites for Boreal and Great Lakes St. Lawrence regions (Rowe, 1972) of the province (Ontario Ministry of Natural Resources 2009a, 2009b; Uhlig et al., 2016). Although these draft Ecoelements and Ecosites are components in the design of the hierarchical provincial Ecological Land Classification system, they are not yet integrated, with some users continuing to use earlier versions of FECs from administrative regions.

In Quebec, the Ministère des Ressources naturelles et des Forêts (MRNF) began the development of a comprehensive Ecological Classification system for the province following the adoption of the Forest Act in 1986 (Grondin et al., 1998). The classification system aims to provide information and tools to guide forest management decisions to ensure sustained yield and multipurpose forest use (Bergeron et al., 1992; Grondin et al., 1998). The system includes an 11-level hierarchy that defines classes by integrating factors of climate, the physical environment (e.g., relief, elevation), and potential vegetation (i.e., forest dynamics) or current vegetation, depending on the classification unit (Saucier et al., 2010). In this way, the system enables description and mapping of provincial ecosystems from continental level "Zones de végétation," characterized by dominant plant formations, through national level "Domaines bioclimatiques," areas of consistent potential vegetation, and their "Sous-domaines," subdivisions based on precipitation regime and dominant natural disturbance, through landscape level units including "Régions écologiques," to local level "Types écologiques" and "Types forestiers (Saucier et al., 2010)." Types écologiques partition the toposequence of Régions écologiques into units with characteristic physical site features (i.e., slope, aspect, position on slope, drainage and nutrient regime) and potential vegetation (Saucier et al., 2010). Types forestiers describe current vegetation using dominant tree species and understory indicator species that reflect local conditions, nutrient regime and successional status (Saucier et al., 2010).

Development of the MRNF classification units for Quebec followed a phytoecological approach (Saucier et al., 2010) based on field sampling and multivariate data analyses of over 28,000 plots (Bergeron et al., 1992; Saucier et al., 2010). Classification development involved a multidisciplinary team responsible for ecological inventory, vegetation classification and ecological mapping, and built on earlier work in Quebec by Grandtner (1966), Lafond (1969) and Jurdant (e.g., Jurdant et al., 1977) primarily (Saucier et al., 2010). It included the participation of government foresters and technicians, specialists from educational institutions and representatives of forest industry (Grondin et al., 1998). A series of ecological classification reports, "Rapports de classification écologique" (e.g., Bergeron et al., 1998; Gosselin et al. 1998; Grondin et al. 1998) present the regional understory indicator species groups and Types écologiques for each bioclimatic subdomain. Field identification guides, "Guides de reconnaissance des types écologiques," provide tools to identify and apply the classification within ecological regions (e.g., Blouin and Berger, 2002; Gosselin et al., 2003; Blouin and Berger, 2005). Types écologiques and Types forestiers can be found in more than one Région écologique (due to ecological equivalence) but the Guides de reconnaissance describe geographical variants for domains or regions in which they occur.

Despite the recognized importance and utility of ecosystem classification to operational planning and silvicultural decision making in Ontario (e.g., Merchant et al., 1989; Racey et al., 1989; Sims and Uhlig, 1992; Lee et al., 1998), Vegetation Types have limited contemporary use. Impediments have likely included a lack of familiarity or training, the existence of multiple regional versions and revisions, a focus on mature forest communities as opposed to young, regenerating stands, and their generality instead of purposeful fit for specific silvicultural applications.

One area of silviculture where such ecological classifications would be particularly useful is with vegetation management. Vegetation management consists of directing forest succession to provide a diverse range of ecosystem services, most often aiming to enhance establishment of seedlings of desired species by reducing the growth of competing plants (Thiffault, 2021). Vegetation management comprises both preventive and corrective approaches (Wiensczyk et al., 2011). Preventive treatments are designed to prevent the invasion of forest sites by species that are incompatible with management objectives. For example, logging that limits soil disturbance or preserves partial cover, or winter logging that restricts the establishment of species that disperse seeds by wind. Corrective treatments consist of silvicultural practices applied soon after harvesting to encourage or create conditions for the regeneration of preferred species, often using chemical herbicides that kill competing species (Wagner et al., 2006).

However, herbicide use directly conflicts with Indigenous values and world views (Kayahara and Armstrong, 2015). Across Canada and elsewhere, social pressure is growing to reduce or eliminate herbicide use in forestry (Ammer et al., 2011; Thiffault and Roy, 2011; Wyatt et al., 2011; Thiffault, 2021). Due to a variety of ecological, social and health concerns, the province of Quebec banned herbicide use in public forests in 2001 (Thiffault and Roy, 2011; Wyatt et al., 2011). In northeastern Ontario, concerns over herbicide use have led to the development of the Herbicide Alternatives Program (HAP). Now in its second phase, HAP 2.0 is a collaborative First Nations, industrial and governmental initiative that aims to develop and implement a strategy to regenerate forests without the use of herbicides (Box 1). One initiative identified by experienced ecologists and silviculturists associated with HAP 2.0, and endorsed by all HAP 2.0 partners, was the development of an ecological framework for classifying sites to identify their competition potential. An efficient technique for reducing herbicide use is to identify ecological sites with inherently limited vegetation competition, or sites where various alternative (non-herbicide) approaches are likely to succeed (Balandier et al., 2006). Such a framework would facilitate the evaluation and comparison of herbicide alternatives across the range of topographic soil and stand conditions.

In this report, we present a first approximation of our ecological framework to support vegetation management decisions in the boreal and northern temperate forests of northeastern Ontario and northwestern Quebec. We have used information from existing classifications for northeastern Ontario and northwestern Quebec, together with inferences regarding post-disturbance communities, to develop this framework specifically for HAP 2.0 applications. It consists of broad, ecologically and silviculturally meaningful overstory and understory classes intended for ground-based application at the plot and/or stand scale. The overall goal is to provide an adaptive ecological framework that: 1) directly addresses silvicultural vegetation management issues and 2) provides a common, consistent language for forest planning, operations, inventory and research. As we learn more about the prevalence, autecology and regional indicator value of certain plant species, and how they respond to various herbicide alternatives, the framework's overstory and understory classes will likely be refined.

Box 1. Herbicide Alternatives Program (HAP) 2.0 background

In 2010, Tembec Inc., (now GreenFirst Forest Products, previously Rayonier Advanced Materials Inc., RYAM), initiated discussions with several northeastern Ontario First Nations communities and organizations, including Mushkegowuk Environmental Research Centre, on the use of herbicides in forestry. This evolved into the Herbicide Alternatives Program (HAP), with the goal of co-developing and implementing a strategy to regenerate forests on the company's tenures in northeastern Ontario using alternatives to the application of chemical herbicides. In the years since, the licence holder has brought HAP principles into its site-based planning for silvicultural operations. In an October 2018 meeting, a group of silviculturists, researchers, Indigenous knowledge keepers, and forestry professionals visited sites in the Martel Forest (as of 2021, part of the Missinaibi Forest), including the Chapleau Crown Game Preserve, for a first-hand look at particular needs and challenges related to forest renewal and forest stand management. The result was an exchange of information among partners who represented industry, federal and provincial governments, an Indigenous enterprise and Indigenous communities.

Partners: GreenFirst Forest Products (formerly RYAM, Tembec), Wahkohtowin Development GP Inc., Brunswick House, Chapleau Cree, Chapleau Ojibwe, Matachewan, Mattagami, Michipicoten, Missinabie Cree and Pic Mobert First Nations, Ontario Ministry of Natural Resources and Forestry, and Natural Resources Canada, Canadian Forest Service (Canadian Wood Fibre Centre and Great Lakes Forestry Centre).

Collaborators: Interfor, Missinaibi Forest Management Inc.

Objective: To build the HAP model into a new phase with an emphasis on knowledge sharing, technology transfer and applied research. A guiding principle of HAP 2.0 is engagement with Indigenous Peoples to encourage connections among Indigenous knowledge, ecological and silvicultural research, and advanced technology. HAP 2.0 is rooted in a sincere desire by Indigenous and western scientific communities to co-create knowledge in a respectful, reciprocal and relational manner, as per the principles of Indigenous research and reconciliation (Wong et al., 2020).

Partnership goal: Successful forest renewal using alternatives to the application of chemical herbicides.

Purpose

Overstory and understory vegetation composition and dynamics are strongly linked to site and soil conditions within a biogeoclimatic zone. Development of an appropriate ecological framework for the study area was therefore viewed as the first step in evaluating the effectiveness of alternative silvicultural treatments on different sites. We used information from various existing classifications and our collective experience to develop this HAP-specific framework. We incorporated the main ecological drivers of vegetation response on upland sites in the region: climate and biogeography, overstory and understory vegetation composition, and site (topographic) and soil factors. We focused on upland sites because these are the sites where herbicide use has historically been concentrated.

Knowledge was drawn from various sources, including: biogeoclimatic zonation (Crins et al., 2009; Saucier et al., 2009; Baldwin et al,. 2021), the range of variability of overstory and understory vegetation conditions occurring on the landscape (Sims et al., 1997; Bergeron et al., 1998; Gosselin et al., 1998; Grondin et al., 1998; Taylor et al., 2000; Blouin and Berger, 2002, 2005; Gosselin, 2003; Ministère des Ressources Naturelles, 2013a, 2013b; Uhlig et al., 2016), indicator species groups (Ministère des Ressources Naturelles, 2013a; Chapman et al., 2020), site and substrate factors affecting competitive vegetation response (Racey et al., 1989; Ministère des Ressources Naturelles, 2013b; Ontario Ministry of Natural Resources and Forestry, 2015), and the suitability of particular silvicultural treatments in the boreal and northern temperate ecosystems of Quebec and Ontario (Racey et al., 1989; Ministère des Ressources Naturelles, 2013b; Ontario Ministry of Natural Resources and Forestry, 2015).

The ecological framework is intended to be applicable to both mature forest stands (to improve prediction of post-disturbance vegetation response), and to understory vegetation communities following disturbance. It is designed to provide sufficient resolution of ecological classes to describe the likely vegetation response, but with broad enough classes for operational use. The framework is also being used to categorize study sites (retrospectively) in a related HAP 2.0 initiative, a digital compendium of vegetation management studies.

Biogeoclimatic zonation

The GreenFirst Forest Products tenures of interest to HAP 2.0 are in northeastern Ontario, an area with similar vegetation, climate and geology to northwestern Quebec (Figure 1; Chapman et al., 2020; Baldwin et al., 2021). This study area falls within the Eastern Boreal Forest and the northern part of the Eastern Temperate Mixed Forest vegetation zones of Canada (Baldwin et al., 2021). In the Canadian National Vegetation Classification (Baldwin et al., 2019a), upland boreal forests in northeastern Ontario are classified with those in northwestern Quebec as Ontario-Quebec Boreal Forest (CM495b) within the Eastern North American Boreal Forest Macrogroup (M495; Baldwin et al., 2017). The northern temperate upland forests in the study area are classified as Humid Eastern Temperate Hardwood – Conifer Forest (CM014b) within the Eastern North American Temperate Hardwood – Conifer Forest Macrogroup (CM014; Baldwin et al., 2019b). The HAP 2.0 ecological framework has been developed specifically to be applied within this biogeoclimatic context based on the relatedness of forest and site conditions in northwestern Quebec with those in northeastern Ontario. These include the western subdomains of the Spruce – Moss, Balsam fir – White birch, and Balsam fir – Yellow birch bioclimatic domains of Quebec (Saucier et al., 2009) and Ecoregions 3E (Lake Abitibi), 4E (Lake Temagami) and (primarily northern) 5E (Georgian Bay) of Ontario (Crins et al., 2009). Beyond this area of northeastern Ontario and northwestern Quebec, as the climate, geology and biogeography shift, vegetation composition and dynamics differ, so the overstory and understory classes that make up the HAP 2.0 ecological framework are likely to become less relevant.

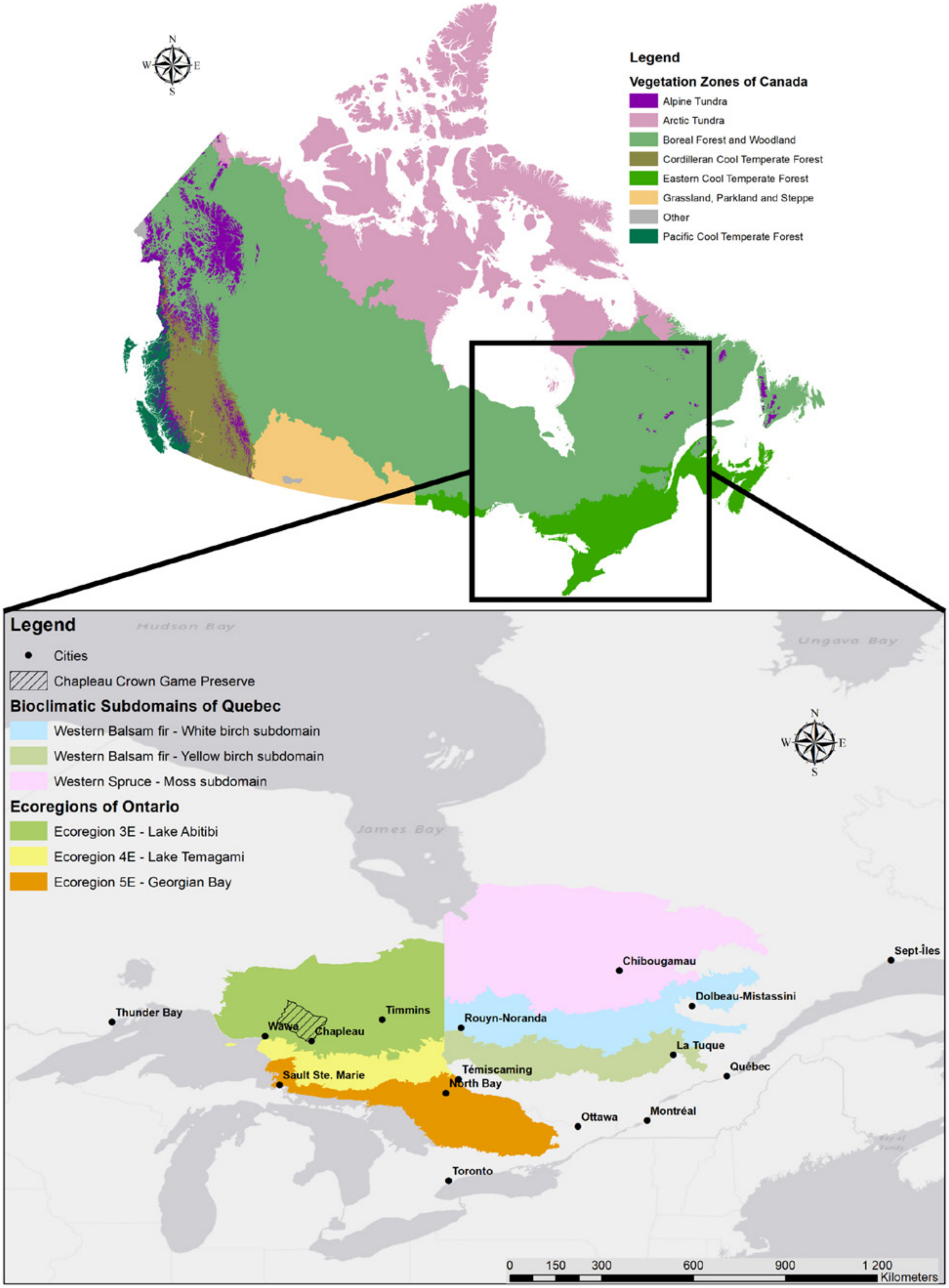

Figure 1. Vegetation zones of Canada (top, Baldwin et al., 2021) with map of portions of Ontario and Quebec showing Ontario Ecoregions (Crins et al., 2009) and Quebec bioclimatic subdomains (Saucier et al., 2009) in which the ecological framework is intended for use. The Chapleau Crown Game Preserve, the original area of interest for HAP, is also shown.

Overstory classes

Overstory composition prior to harvest is an important component of the ecological framework. The tree species that are present on a site provide useful information for advanced planning of silvicultural approaches and operational needs, and for anticipating post-harvest plan modifications that may be required. Dominant tree species composition reflects regional climate, disturbance regime and site conditions (Figure 2), and thus influences a variety of silvicultural decisions that affect post-harvest vegetation response (e.g., Roberts, 2007; Bell et al., 2011a). From the variety of silvicultural and ecological classifications that exist for Ontario and Quebec, we developed HAP 2.0 overstory classes based on Quebec's "Groupement d'essences principales" (further referred to as principal species groups) and "Grand type de couvert forestier" (or grand cover types; Table 1; Ministère des Ressources Naturelles, 2013b). Quebec's principal species groups, which are based on dominant tree species composition, are practical as well as ecologically and silviculturally meaningful. They are organized into grand cover types that reflect climate and overriding disturbance regime, which are the main factors that affect the choice of silviculture system (Table 1; Ministère des Ressources Naturelles, 2013b).

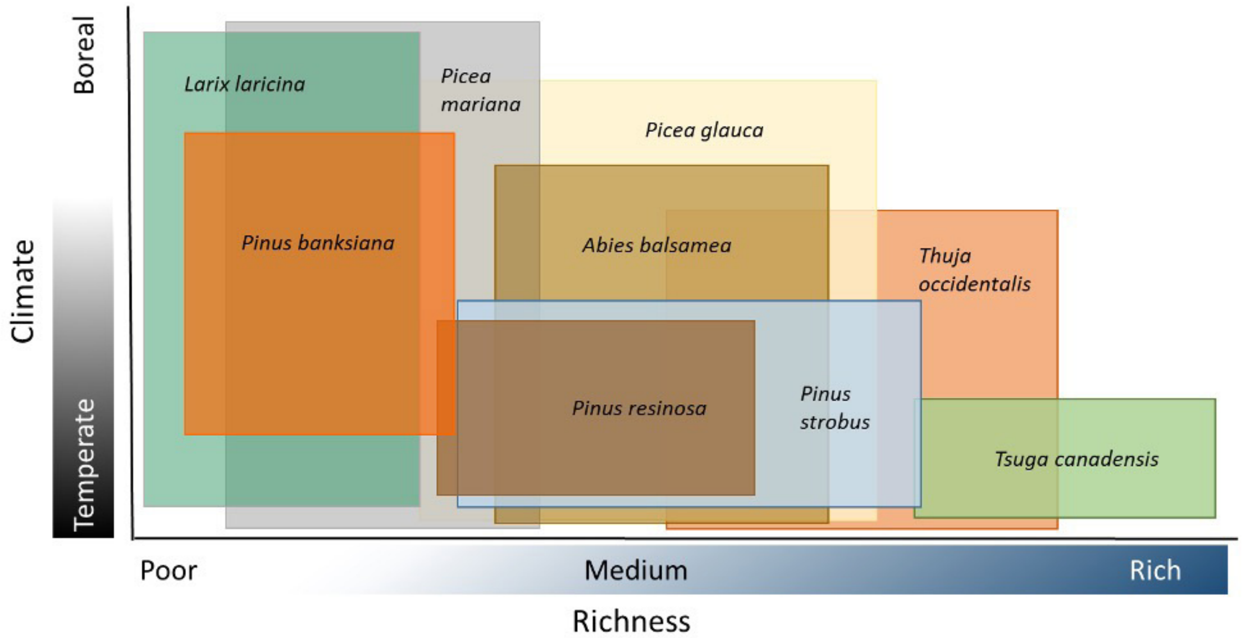

Figure 2. Conceptual distributions of dominant boreal and temperate conifer species in Ontario and Quebec arranged along gradients of climate and site richness (adapted from Ministère des Ressources Naturelles, 2013a). The scientific names and authorities, and common English and French names of tree species included in this report are provided in Table A1.

Table 1. Quebec grand cover type, principal species group (translated from Ministère des Ressources Naturelles, 2013b), and HAP 2.0 overstory class. X indicates temperate groups omitted from HAP 2.0 overstory classes because they are not typically treated with herbicides or outside the HAP area of interest (Figure 1). Tree species' scientific names and authorities, and common English and French names are provided in Table A1.

Grand cover type	Principal species group	HAP 2.0 Overstory class
Transitional hardwood	Trembling aspen, Balsam poplar, Large-toothed aspen	1
Transitional hardwood	Paper birch, Grey birch	2
Boreal coniferous and mixedwood	Black spruce – Trembling aspen	1
Boreal coniferous and mixedwood	Black spruce	4
Boreal coniferous and mixedwood	Jack pine	4
Boreal coniferous and mixedwood	Tamarack	4
Boreal coniferous and mixedwood	Balsam fir – Paper birch	2
Boreal coniferous and mixedwood	Balsam fir	3
Boreal coniferous and mixedwood	White spruce	3
Temperate oak and pine	White pine	5
Temperate oak and pine	Red pine	5
Temperate oak and pine	Red oak	x
Temperate mixedwood and coniferous	Balsam fir – Yellow birch	8
Temperate mixedwood and coniferous	Yellow birch – Conifer	8
Temperate mixedwood and coniferous	Balsam fir – Red maple	8
Temperate mixedwood and coniferous	Eastern white cedar	6
Temperate mixedwood and coniferous	Eastern hemlock	7
Temperate mixedwood and coniferous	Balsam fir – Red spruce	x
Temperate hardwood	Maple – Hardwood with low shade tolerance	x
Temperate hardwood	Maple – shade tolerant Hardwood	x
Temperate hardwood	Yellow birch – Sugar maple	x

We compared these principal species groups to overstory species combinations used in other silvicultural and ecological classifications in Ontario and Quebec. We then combined principal species groups known to occur on similar site conditions, often interspersed in mixtures, and species groups that we anticipated would respond similarly to particular silvicultural treatments. For example, we combined *Pinus banksiana* (jack pine), *Picea mariana* (black spruce) and *Larix laricina* (tamarack) groups into HAP 2.0 overstory class 4 (Table 1), as these species often occur together on cool (more boreal) and relatively nutrient-poor sites (Figure 2). We developed eight HAP 2.0 overstory classes from the 18 principal species groups that remained after eliminating temperate hardwood groups not typically treated with herbicides, and the *Abies balsamea* (balsam fir) and *Picea rubens* (red spruce) temperate group that does not occur in our HAP area of interest (Table 1, Figure 1).

The eight HAP 2.0 overstory classes and their diagnostic criteria are included in Table 2. The classes follow the principle that if a tree species indicative of a warmer (more temperate), and/or richer site condition (Figure 2) is present (>10% cover), the site is better classified in the warmer or richer class. Because *Populus* spp. (poplar spp.) are very competitive with conifer crop trees, a low threshold of cover (≥25%) is proposed for classifying stands into overstory class 1 [*Populus* spp. (poplar spp.) Hardwood and Mixedwood].

Table 2. HAP 2.0 overstory classes and their proposed diagnostic criteria (% values indicate cover). Note that "temperate spp." refers to *Acer rubrum, Acer saccharum, Betula alleghaniensis, Pinus strobus, Pinus resinosa, Quercus rubra, Thuja occidentalis* and *Tsuga canadensis.* Tree species' scientific names and authorities, and common English and French names are provided in Table A1.

HAP 2.0 Overstory Class	Criteria
1. *Populus* spp. (Trembling aspen, Large-toothed aspen, Balsam poplar) Hardwood and Mixedwood	Stands with *Populus* spp. + *Betula papyrifera* ≥25%; *Populus* spp. > *Betula papyrifera*; <10% temperate spp. (excluding *P. grandidentata*).
2. *Betula papyrifera* (Paper birch) Hardwood and Hardwood-dominated Mixedwood	All *Betula papyrifera*-dominated hardwood and hardwood-dominated mixedwood stands; *Betula papyrifera* + *Populus tremuloides* ≥50%; *Betula papyrifera* > *Populus* spp.; <50% conifer; <10% temperate spp.
3. *Abies balsamea* (Balsam fir) and/or *Picea glauca* (White spruce)-dominated Conifer and Mixedwood	Conifer and mixedwood stands dominated by *Abies balsamea* and/or *Picea glauca* with or without *Betula papyrifera*; ≥50% conifers; *Abies balsamea* + *Picea glauca* > *Pinus banksiana* + *Picea mariana*; <50% hardwoods; <10% temperate spp. In mixes with *P. mariana*, *A. balsamea* ≥35% distinguishes this class from #4.
4. *Pinus banksiana* (Jack pine), *Picea mariana* (Black spruce), and/or *Larix laricina* (Tamarack) Conifer	Conifer stands (≥75% conifer spp.) with any of *Pinus banksiana*, *Picea mariana* and/or *Larix laricina* dominant; <25% hardwoods; <35% *Abies balsamea* (otherwise #3); <10% temperate spp.
5. *Pinus strobus* (White pine) and/or *Pinus resinosa* (Red pine) Conifer and Mixedwood	Conifer and mixedwood stands with *Pinus strobus* + *Pinus resinosa* ≥30%; <10% *Thuja occidentalis*; <30% *Tsuga canadensis*.
6. *Thuja occidentalis* (Eastern white cedar) Conifer and Mixedwood	Conifer and mixedwood stands with *Thuja occidentalis* ≥10%; <30% *Tsuga canadensis*.
7. *Tsuga canadensis* (Eastern hemlock) Conifer and Mixedwood	Conifer and mixedwood stands with *Tsuga canadensis* ≥30%.
8. *Betula alleghaniensis* (Yellow birch) and/or *Acer rubrum* (Red maple) Mixedwood	Mixedwood stands with a hardwood component of *Betula alleghaniensis* + *Acer rubrum* ≥25%, with <30% *Pinus strobus* + *Pinus resinosa* (otherwise #5), <10% *Thuja occidentalis* (#6), and <30% *Tsuga canadensis* (#7).

Understory classes

Many of the tree species included in our HAP 2.0 overstory classes can occur on a broad range of site conditions (Figure 2; e.g., Carleton and Maycock, 1978; Bergeron and Bouchard 1984; Bergeron and Dubuc, 1989; Sims et al., 1990, 1996; Harvey et al., 1996; Frelich 2002). Overstory classes alone are insufficient for classifying sites for HAP 2.0 purposes. Therefore, our ecological framework relies heavily on understory classes, which comprise groups of plant species that are known indicators of site-specific soil moisture and nutrient conditions within boreal and northern temperate forests of northeastern Ontario and northwestern Quebec (Ministère des Ressources Naturelles, 2013a; Chapman et al., 2020).

We used Quebec's "Groupes écologiques élémentaires" (further referred to as indicator species groups; Ministère des Ressources Naturelles, 2013a) as building blocks for HAP 2.0 understory classes (Figure 3). An indicator species group (ISG) is a suite of understory species (i.e., shrubs, forbs, grasses, ferns, mosses and lichens) that commonly occur together and have ecological affinity for a particular environment. Quebec's ISGs were developed for Quebec bioclimatic subdomains through analyses of ecological plot data in relation to a variety of site physical characteristics and stand successional stages (e.g., Bergeron et al., 1998). ISGs are related to soil moisture and nutrient conditions (Appendix 2) but vary slightly in their expression in regions with different climatic conditions (i.e., more boreal or more temperate, Figure 3), stand origin type, and time since disturbance.

Although indicator species groups have not been developed using quantitative methods for our study area in northeastern Ontario, the Quebec ISGs are consistent with expert opinion-derived groups of indicator species used in Ontario for both the new boreal Vegetation Types (Uhlig et al., 2016) and the Canadian National Vegetation Classification (CNVC) Eastern Boreal Forest Associations (Baldwin et al., 2019a; Chapman et al., 2020).

To develop our eight HAP 2.0 understory classes, we combined Quebec's ISGs that reflect similar soil moisture and nutrient conditions, which we anticipated would respond similarly to particular silvicultural treatments (Figure 3). We used additional resources to further inform our knowledge of these groups (Bergeron et al., 1998; Grondin et al., 1998; Gosselin et al., 1998, 2003; Blouin and Berger, 2002, 2005).

The conceptual distributions of the resulting HAP 2.0 understory classes are arranged along gradients of soil moisture and soil nutrient availability (Figure 4). The overlap of classes in the figure indicates that although a given indicator species group characterizes a particular understory class, it may not be unique to that class. For example, the AUR ISG occurs in both the Moist Rich Shrub and Herb and the Moist Medium Transition understory classes (Figure 3). The overall suite of species is important to consider when classifying a given site. Both presence and abundance (cover) of species are indicative of site condition. Typically, if a richer suite of species is present, the richer class is assigned to a site. In classifying the understory, it is also necessary to consider the extent of overstory cover. A closed forest stand can limit light and moisture availability, and thus the development of certain understory species, so examining nearby canopy gaps can be useful for understanding this potential effect.

HAP 2.0 Understory Class	Indicator Species Group (ISG)			
	Boreal		Temperate	
	Code	Species	Code	Species
Lichen	CLA	*Cladina* sp.	VAA	*Cladina* sp.
		Cladina mitis		*Cladina mitis*
		Cladina rangiferina		*Cladina rangiferina*
		Cladina stellaris		*Cladina stellaris*
				Dicranum sp.
				Gaultheria procumbens
				Vaccinium angustifolium
Ericaceous Shrub	KAA	*Kalmia angustifolia*	VAM	*Kalmia angustifolia*
		Vaccinium angustifolium		*Linnaea borealis*
		Vaccinium myrtilloides		*Vaccinium myrtilloides*
	LEG	*Rhododendron groenlandicum*		
Feathermoss or Mesophytic Herb	AUC	*Alnus viridis* ssp. *crispa*	CLB	*Amelanchier* sp.
		Amelanchier sp.		*Clintonia borealis*
		*Ilex mucronata**		*Cornus canadensis*
		Viburnum nudum var. *cassinoides**		*Lysimachia borealis*
	CON	*Aralia nudicaulis*		*Maianthemum canadense*
		Clintonia borealis	DIE	*Diervilla lonicera*
		Coptis trifolia		*Eurybia macrophylla*
		Cornus canadensis		*Pteridium aquilinum*
		Linnaea borealis	PLS	*Bazzania trilobata*
		Lysimachia borealis		*Hylocomium splendens*
		Maianthemum canadense		*Pleurozium schreberi*
		Pyrola sp.		*Polytrichum* sp.
	DIE	*Diervilla lonicera*	OXM	*Coptis trifolia*
		Eurybia macrophylla		*Oxalis montana*
		Pteridium aquilinum		*Sorbus americana*
	HYS	*Hylocomium splendens*		*Viburnum nudum* var. *cassinoides*
	PLS	*Dicranum* sp.		
		Pleurozium schreberi		
		Ptilium crista-castrensis		
	DRS	*Dryopteris spinulosa*		
		Oxalis montana		
Disturbed Mesic to Moist, Medium to Rich	RUI	*Chamaenerion angustifolium*	RUI	*Rubus idaeus*
		Fragaria sp.		
		Hieracium sp.		
		Rubus idaeus		
	PRP	*Prunus pensylvanica*		
Mesic Rich Shrub	ERE	*Acer spicatum*	ERE	*Acer spicatum*
		Corylus cornuta		*Aralia nudicaulis*
		Sambucus racemosa		*Corylus cornuta*
		Taxus canadensis		*Dryopteris spinulosa*
				Lonicera canadensis
			ERP	*Acer pensylvanicum*
				Maianthemum racemosum
				Medeola virginiana
				Polygonatum pubescens
				Taxus canadensis
			VIL	*Dendrolycopodium obscurum*
				Huperzia lucidula
				Streptopus lanceolatus
				Viburnum lantanoides
Moist Rich Shrub and Herb	AUR	*Alnus incana* ssp. *rugosa*	AUR	*Alnus incana* ssp. *rugosa*
		Equisetum sp.		*Osmundastrum cinnamomeum*
	RUP	*Athyrium filix-femina*	RUP	*Cornus alternifolia*
		Galium sp.		*Mnium* sp.
		Gymnocarpium dryopteris		*Phegopteris connectilis*
		Mitella nuda		*Rubus pubescens*
		Mnium sp.	TIC	*Athyrium filix-femina*
		Osmunda claytoniana		*Gymnocarpium dryopteris*
		Osmundastrum cinnamomeum		*Oclemena acuminata*
		Ribes glandulosum		*Osmunda claytoniana*
		Rubus pubescens		*Tiarella cordifolia*
				Viola sp.
Moist Medium Transition	SPS	*Sphagnum* sp.	SPS	*Sphagnum* sp.
	PLS	*Dicranum* sp.		*Ilex mucronata*
		Pleurozium schreberi	PLS	*Bazzania trilobata*
		Ptilium crista-castrensis		*Hylocomium splendens*
	AUR	*Alnus incana* ssp. *rugosa*		*Pleurozium schreberi*
		Equisetum sp.		*Polytrichum* sp.
	LEG	*Rhododendron groenlandicum*	AUR	*Alnus incana* ssp. *rugosa*
				Osmundastrum cinnamomeum
Wet	SPS	*Sphagnum* sp.	SPS	*Sphagnum* sp.
	CAL	*Chamaedaphne calyculata*		*Ilex mucronata*
		Kalmia polifolia	GRS	*Carex* sp.
		Maianthemum trifolium		*Gramineae*
	CAX	*Carex* sp.		*Salix* sp.
	GRS	*Gramineae*		

*may be less important in NE Ontario and more indicative of moister conditions; requires further review

Figure 3. HAP 2.0 understory classes with their component Quebec indicator species groups (ISGs) (shown with original 3-letter codes in bold; from Ministère des Ressources Naturelles, 2013a). Species' scientific names and authorities, English and French common names and lifeforms are provided in Table A2.

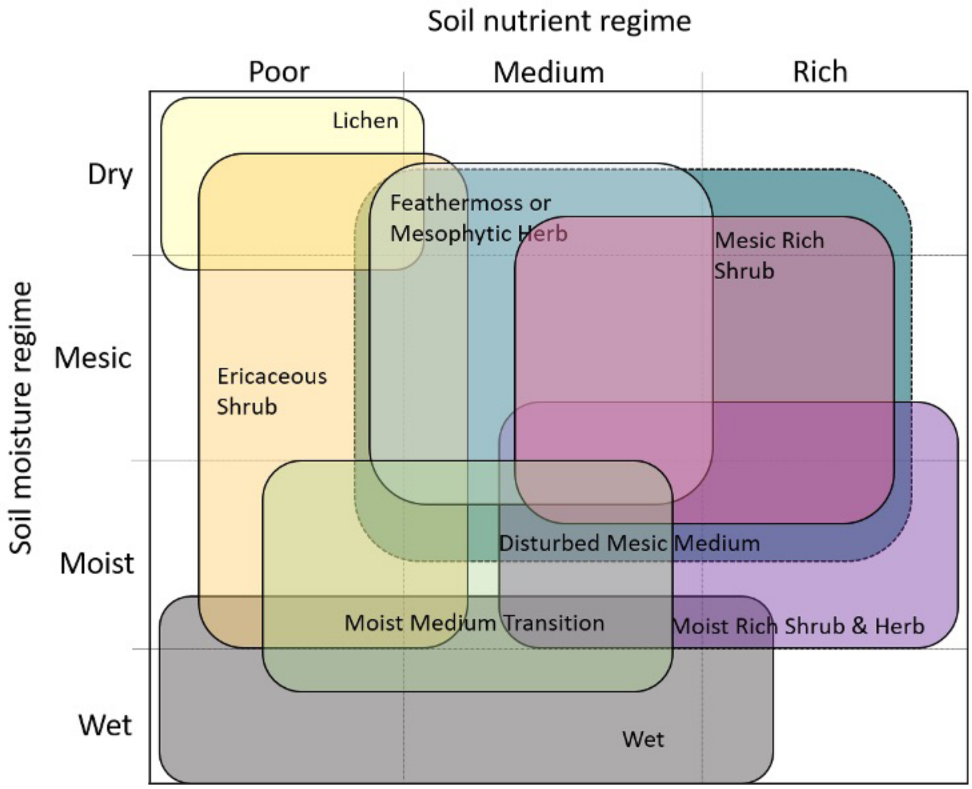

Figure 4. Conceptual distributions of each HAP 2.0 understory class arranged along gradients of soil moisture and soil nutrient regimes. Indicator species of each HAP 2.0 understory class are listed in Figure 3.

We used our knowledge and experience, together with information associated with new Ontario Vegetation Types (Uhlig et al., 2016), CNVC Eastern Boreal Forest Associations (Chapman et al., 2020) and classification reports for the western subdomains of the Spruce – Moss (Bergeron et al., 1998), Balsam fir – White birch (Grondin et al., 1998), and Balsam fir – Yellow birch bioclimatic domains (Gosselin et al., 1998) of Quebec, to characterize the most common site and soil characteristics affiliated with each understory class (Table 3), and to determine combinations of overstory and understory classes that are likely to occur within northeastern Ontario and northwestern Quebec (Table 4).

Most of Quebec's ISGs (Figure 3) that we have combined in HAP 2.0 understory classes best describe more stable, mature (~40 years or older) forest understories. Ministère des Ressources Naturelles (2013a) also provides a "perturbation" diagram of ISGs arranged along gradients of site moisture and richness for disturbed sites (Figure A1). Theses ISGs are relevant to both boreal and temperate sites, although their occurrence may vary regionally. The ericaceous-dominated KAA and LEG groups are more characteristic of the boreal, and the ERE and PRP ISGs are more characteristic of the temperate. Many of the ISGs in the perturbation figure also occur under mature forest canopies (Figures A2-A4), although species typically occur at much reduced cover compared to recently disturbed sites. However, one of the perturbation ISGs, (RUI and PRP, Figure 3), which is dominated by early seral species, defines a distinct HAP 2.0 understory class (Disturbed Mesic to Moist, Medium to Rich) and is not characteristic of mature forests.

Table 3. Site and substrate characteristics most likely associated with each of the HAP 2.0 understory classes. Class definitions are provided in Table A3.

Site or Substrate Variable	A. Lichen	B. Ericaceous Shrub	C. Feathermoss or Mesophytic Herb	D. Disturbed Mesic to Moist, Medium to Rich	E. Mesic Rich Shrub	F. Moist Rich Shrub and Herb	G. Moist Medium Transition	H. Wet
Mode of deposition	bedrock; morainal/till; glaciofluvial	morainal/till; glaciofluvial*	morainal/till; glaciofluvial*	morainal/till; glaciofluvial*; lacustrine	morainal/till; glaciofluvial; lacustrine	glaciofluvial; lacustrine	glaciofluvial; lacustrine; organic (commonly with a variable depth peat over mineral substrate)	organic
Slope position	crest; upper; mid; level	upper; mid; lower; level	upper; mid; level	mid; lower; level	mid; lower; level	lower; level	lower; level	level; depression
Slope gradient	level to moderate	level to moderately steep	level to steep	level to moderately steep	level to moderate	level to moderate	level to moderate	level
Coarse fragment content	low to high	low to high	low to moderate	low to moderate	low to moderate	low	low	low
Substrate depth	Highly variable depending on mode of deposition	moderately deep to deep	moderately deep to deep	any	moderately deep to deep	moderately deep to deep	deep	deep peat deposit
Texture class	coarse sandy to coarse loamy	coarse sandy to coarse loamy	coarse loamy to fine loamy	coarse loamy to fine loamy	coarse loamy to fine loamy (could be underlain by clay)	coarse loamy to fine loamy (could be underlain by clay)	fine loamy to clayey	organic (commonly dominated by Of horizons)
Drainage	rapid	well to imperfect	well to moderately well	well to imperfect	well to imperfect	moderately well to imperfect	imperfect to poor	poor
Humus form	mor (fibrimor)	mor (fibrimor to humimor)	mor (fibrimor to humimor)	mor; moder	mor (humimor); moder	moder; mull	mor (humimor); peatymor; moder	peatymor; organic
Soil moisture regime	dry	dry to moist	mesic	mesic to moist	mesic to moist	moist	moist to wet	wet
Soil nutrient regime	poor	poor	medium	medium to rich	medium to rich	medium to rich	poor to medium	poor to medium

* Variable depth wind blown caps of finer (commonly Silty very fine Sand) material commonly occur in concert with these morainal tills and glaciofluvial deposits.

Table 4. Combinations of HAP 2.0 overstory (rows) and understory (columns) classes that are likely to occur on the landscape. The overstory classes grade from white (boreal) to black (temperate). The lighter shades in the grid indicate combinations that are less likely to occur. Overstory class criteria are provided in Table 2. Indicator species of each understory class are listed in Figure 3 and understory class criteria are provided in Table 5. Scientific names, authorities and common English and French names for each species are included in Appendix 1.

HAP 2.0 Overstory classes (rows) and Understory classes (columns)	**A. Lichen**	**B. Ericaceous Shrub**	**C. Feathermoss or Mesophytic Herb**	**D. Disturbed Mesic to Moist, Medium to Rich**	**E. Mesic Rich Shrub**	**F. Moist Rich Shrub and Herb**	**G. Moist Medium Transition**	**H. Wet**
1. *Populus* spp. (Trembling aspen, Large-toothed aspen, Balsam poplar) Hardwood and Mixedwood								
2. *Betula papyrifera* (Paper birch) Hardwood and Hardwood-dominated Mixedwood								
3. *Abies balsamea* (Balsam fir) and/or *Picea glauca* (White spruce)-dominated Conifer and Mixedwood								
4. *Pinus banksiana* (Jack pine), *Picea mariana* (Black spruce) and/or *Larix laricina* (Tamarack) Conifer								
5. *Pinus strobus* (White pine) and/or *Pinus resinosa* (Red pine) Conifer and Mixedwood								
6. *Thuja occidentalis* (Eastern white cedar) Conifer and Mixedwood								
7. *Tsuga canadensis* (Eastern hemlock) Conifer and Mixedwood								
8. *Betula alleghaniensis* (Yellow birch) and/or *Acer rubrum* (Red maple) Mixedwood								

The eight HAP 2.0 understory classes are described in the following sections, together with their component ISGs (Figure 3) and diagnostic vegetation criteria (Table 5). The site and substrate characteristics most likely associated with each class are presented in Table 3. HAP 2.0 overstory classes frequently associated with each understory class are shown in Table 4. In the descriptions that follow, we note the need for review of certain species, some that we think may play a more significant indicator role in northeastern Ontario, as well as some that may differ in their indicator status between northeastern Ontario and boreal or temperate Quebec.

Table 5. HAP 2.0 Understory classes, component indicator species groups (ISGs) and proposed vegetation criteria for distinguishing classes (% values indicate cover). The species included in each ISG are listed in Figure 3. English and French common names for each species are included in Table A2.

	Indicator Species Group		
HAP 2.0 Understory Class	**Boreal**	**Temperate**	**Criteria**
A. Lichen	CLA	VAA	CLA, VAA ≥20%; <20% SPS, CAL, CAX, GRS
B. Ericaceous Shrub	KAA, LEG	VAM	KAA, LEG, VAM ≥15%; <20% CLA, VAA; <20% SPS, CAL, CAX, GRS
C. Feathermoss or Mesophytic Herb	AUC, CON, DIE, HYS, PLS, DRS	CLB, DIE, PLS, OXM	<20% CLA, VAA; <15% KAA, LEG, VAM; <20% SPS, CAL, CAX, GRS; <15% ERE, ERP, VIL; <15% AUR, RUP, TIC
D. Disturbed Mesic to Moist, Medium to Rich	RUI, PRP	RUI	RUI, PRP ≥15%
E. Mesic Rich Shrub	ERE	ERE, ERP, VIL	ERE, ERP, VIL ≥15%; <15% AUR, RUP, TIC
F. Moist Rich Shrub and Herb	AUR, RUP	AUR, RUP, TIC	AUR, RUP, TIC ≥15%; <15% LEG
G. Moist Medium Transition	SPS, PLS, AUR, LEG	SPS, PLS, AUR	SPS ≥20%; PLS ≥ SPS
H. Wet	SPS, CAL, CAX, GRS	SPS, GRS	SPS ≥ PLS and/or ≥20% CAL, CAX, GRS

A. Lichen

The Lichen understory class occupies the driest, poorest treed sites (Figure 4). In addition to having site and soil characteristics consistent with drier, nutrient-impoverished conditions (Table 3), this class is assigned to sites that would typically have at least 20% cover of the CLA ISG on more boreal sites or VAA on more temperate sites (Figure 3, Table 5). CLA cover can also be abundant on the Sphagnum hummocks of wet sites, but site conditions (Table 3) and absence of other indicator species of the Wet understory class distinguish between these classes (Figure 3, Table 5).

In addition to the indicator species of the CLA and VAA groups, *Arctostaphylos uva-ursi* and *Comptonia peregrina* might be indicative of the Lichen understory class in northeastern Ontario and could be considered for review.

The Lichen class occurs with overstory class 4 [*Pinus banksiana*, *Picea mariana* and/or *Larix laricina* Conifer], and infrequently with class 5 [*Pinus strobus* and/or *Pinus resinosa* Conifer and Mixedwood] (Table 4, Figures A2 and A4). The CLA and VAA ISGs are not shown in Quebec's perturbation grid of ISGs (Figure A1), but the Lichen understory class likely persists post-disturbance because disturbances that increase light can promote the growth of *Cladina* spp. (Saliha, 2011).

B. Ericaceous Shrub

The Ericaceous Shrub understory class occurs on nutrient-poor, dry to moist sites (Figure 3, Table 3). This class is characterized by having at least 15% cover of the KAA and LEG ISGs on boreal sites or VAM on more temperate sites, with less than 20% cover of the CLA (boreal) or VAA groups (Figure 3, Table 5). The ISGs of this understory class can also occur on wet sites, but in addition to site and soil indicators of the Wet understory class (Table 3), Wet class sites would typically have at least 20% of the SPS, CAL, CAX, and/or GRS ISGs (Figure 3, Table 5). The KAA and LEG ISGs are shown in Quebec's perturbation grid (Figure A1); they can persist post-disturbance.

The Ericaceous Shrub class occurs mainly with overstory class 4 [*Pinus banksiana*, *Picea mariana* and/or *Larix laricina* Conifer], but also with classes 2 [*Betula papyrifera* Hardwood and Hardwood-dominated Mixedwood] and 3 [*Abies balsamea* and/or *Picea glauca*-dominated Conifer and Mixedwood] and might occur infrequently with class 5 [*Pinus strobus* and/or *Pinus resinosa* Conifer and Mixedwood] (Table 4, Figures A2–A4).

C. Feathermoss or Mesophytic Herb

The Feathermoss or Mesophytic Herb understory class occurs on mesic, nutrient-medium sites (Figure 4, Table 3). These are average (zonal) site conditions and include many boreal (AUC, CON, DIE, HYS, PLS, and DRS), and temperate (CLB, DIE, PLS and OXM) ISGs (Figure 3, Table 5). Sites described by this understory class may be easier to define by what they are not; these sites do not meet threshold levels of ISGs of other understory classes (Table 5). Of all the ISGs included in this understory class, only DIE is shown in Quebec's perturbation grid (Figure A1). The Feathermoss or Mesophytic Herb understory class occurs with all the overstory classes (Table 4).

Based on CNVC association development (Baldwin et al., 2019a; Chapman et al., 2020), some additional species such as *Rosa acicularis* and *Sorbus decora* may be good regional indicators of this understory class within the study area, and should be further reviewed for inclusion in this class. Conversely, the AUC ISG includes *Ilex mucronata* (= *Nemopanthus mucronatus*) and *Viburnum nudum var. cassinoides* (= *Viburnum cassinoides*). These species may be more indicative of moister conditions in northeastern Ontario and require further review for their indicator status in northeastern Ontario.

D. Disturbed Mesic to Moist, Medium to Rich

The Disturbed Mesic to Moist, Medium to Rich understory class can occur following disturbance of any of the overstory classes that occur on mesic to moist, nutrient-medium to rich sites (Figure 3, Table 4). This class is characterized by having >15% cover of the early seral species of the RUI and PRP ISGs, <15% of the ERE, ERP, VIL species that characterize the Mesic Rich Shrub class and <25% of the Wet class ISGs (Figure 3, Table 5). Conceptually, it occupies conditions between the DIE ISG (in the Feathermoss or Mesophytic Herb class) on slightly drier sites, and the ERE ISG (in the Mesic Rich Shrub class) on slightly moister, richer sites (Figure A1). It can overlap somewhat with the Mesic Rich Shrub class (Figure 4), but because the RUI/PRP suite of species has different competitive effects than the ERE group that characterizes the Mesic Rich Shrub class, we have kept the two classes distinct.

Prunus virginiana is not included in the RUI and PRP ISGs but could be considered for review in this class.

E. Mesic Rich Shrub

The Mesic Rich Shrub understory class is characterised by >15% cover of the ERE boreal ISG or ERE, ERP and VIL temperate ISGs (Figure 3, Table 5). These ISGs are indicative of mesic to moist, nutrient-medium to rich sites (Figure 3, Figures A2–A4). The ERE ISG is shown in Quebec's perturbation grid (Figure A1).

This understory class can occur with all overstory classes but is less likely to occur with classes 4 [*Pinus banksiana*, *Picea mariana* and/or *Larix laricina* Conifer] and 6 [*Thuja occidentalis* Conifer and Mixedwood] (Table 4).

F. Moist Rich Shrub and Herb

The Moist Rich Shrub and Herb understory class occurs on moist, rich sites (Figure 4, Figures A2–A4). It is characterized by the AUR and RUP ISGs on boreal sites and the AUR, RUP, and TIC ISGs on temperate sites (Figure 3). The Moist Medium Transition and Wet understory classes can also include cover of some of these species, especially *Alnus incana* ssp. *rugosa*. To distinguish these classes, in addition to site conditions (Table 3), the Moist Rich Shrub and Herb class should have >15% cover of AUR, RUP and TIC with <15% cover of LEG and <20% of SPS or other ISGs of the Wet class

(Table 5). The AUR ISG is shown in Quebec's perturbation grid (Figure A1).

Cornus sericea (= *Cornus stolonifera*) is not included in Quebec's ISGs but may be indicative of this understory class in northeastern Ontario and could be considered for further review.

This understory class occurs with overstory classes 1 [*Populus* spp. Hardwood and Mixedwood], 3 [*Abies balsamea* and/or *Picea glauca*-dominated Conifer and Mixedwood], 4 [*Pinus banksiana*, *Picea mariana* and/or *Larix laricina* Conifer], 6 [*Thuja occidentalis* Conifer and Mixedwood], and 8 [*Betula alleghaniensis* and/or *Acer rubrum* Mixedwood] (Table 4).

G. Moist Medium Transition

The Moist Medium Transition understory class occurs on moist, nutrient-medium sites that are transitional between uplands and lowlands (Figure 3, Table 3). As ecotonal sites, they may include ISGs characteristic of other understory classes (Figure 3, Table 5). Site and soil conditions are especially important diagnostic criteria for this class (Table 3). Such sites often have Gleysol soils (Soil Classification Working Group, 1998) with mottling in the top of the soil profile (but beginning > 5cm from the organic-mineral interface), and commonly have a deep, peaty-phase humic layer. In addition to the boreal LEG ISG, other boreal and temperate ISGs include: SPS, PLS and AUR (Figure 3, Table 5). Sites in this class often have SPS >20%, with PLS >SPS, whereas on Wet class sites, SPS is often >PLS. SPS, AUR and LEG are included in Quebec's perturbation grid (Figure A1).

This understory class occurs with overstory classes 4 [*Pinus banksiana*, *Picea mariana* and/or *Larix laricina* Conifer] and 6 [*Thuja occidentalis* Conifer and Mixedwood], and might occur infrequently with 3 [*Abies balsamea* and/or *Picea glauca*-dominated Conifer and Mixedwood] (Table 4).

H. Wet

The Wet understory class includes ISGs of wet sites, ranging from poor to medium richness (Figure 4, Figures A2–A4). These include boreal ISGs: SPS, CAL, CAX and GRS and temperate ISGs: SPS and GRS (Figure 3) usually with cover >20% (Table 5). The GRS and SPS ISGs are shown in Quebec's perturbation grid (Figure A1). Sites in the Wet understory class typically are not treated with herbicides and are less relevant to HAP 2.0. Indicators of poor and medium nutrient conditions are not distinguished as distinct understory classes.

This understory class is associated with overstory classes 4 [*Pinus banksiana*, *Picea mariana* and/or *Larix laricina* Conifer] and 6 [*Thuja occidentalis* Conifer and Mixedwood] (Table 4).

Discussion

We used several existing ecological classifications, as well as expert opinion, to develop this first approximation of an ecological framework for HAP 2.0 purposes. The classification aims to simplify site characterization to the elements most likely to contribute to vegetation response following harvest. These include climate and biogeography, overstory and understory vegetation composition, and site and soil factors. We aimed for a "reasonable" number of ecologically and silviculturally meaningful combinations of overstory to facilitate framework use. As a result, the classes are fairly broad, but should be sufficiently robust for HAP 2.0 purposes.

As the ecological framework is applied in HAP 2.0 initiatives by forest ecologists, silviculturists, researchers, forest industry practitioners, and First Nations lands and resources officers, we anticipate that new knowledge regarding patterns of vegetation succession and competition will guide its refinement. On-the-ground application will help further our understanding of the prevalence, autecology and regional indicator value of certain plant species, which may necessitate changes to our understory classes (i.e., indicator species selection and threshold cover criteria).

The framework is currently being used to retrospectively classify the ecological conditions of study sites in a companion HAP 2.0 initiative, a digital compendium of longer-term vegetation management studies for the region. This will facilitate synthesizing responses to vegetation management treatments by site type (and identifying site-related knowledge gaps) and evaluating their effectiveness in terms of site conditions. The framework also supports sharing site-specific knowledge and best practices across the boreal and northern temperate regions to which it applies (including between northeastern Ontario, where herbicides are still being used, and northwestern Quebec, where they are not).

Together the framework and compendium will help guide the development of site-specific recommendations for herbicide alternatives (e.g., methods and timing of various harvest, site preparation, regeneration and tending activities). The need for such decision support tools to help reduce or eliminate herbicide use has been stressed by HAP 2.0 partners.

Although the overstory and understory classes of the framework are designed to be applied to mature forests in ground-based assessments, at a broader scale, applying concepts from the framework may support longer-term silvicultural planning. Identifying overstory classes and particular site and soil variables through remote sensing and soil mapping may enable better identification and estimation of areas that will require specific silvicultural treatments (e.g., larger stock sizes, motor-manual tending), improving overall efficiency and cost-effectiveness. Linking the framework with such initiatives is an important consideration going forward.

The ecological framework provides a common language for HAP 2.0 partners to use to describe site types and share knowledge of vegetation management research and experiences. Field foresters and researchers may already recognize the patterns and inter-relatedness of the site, soil and vegetation components of this framework. However, the framework per se provides a common language for all and a tool to transfer this knowledge to new practitioners and collaborators.

Conclusion

This report presents our first approximation of an ecological framework for classifying sites for HAP 2.0 in northeastern Ontario. The intent is to provide all HAP 2.0 partners (Box 1) with a common foundation and consistent ecological language for describing specific site conditions relevant to post-harvest vegetation development and herbicide alternatives. This first approximation is an initial step. Going forward, we anticipate that the various HAP 2.0 partners will co-develop a plan to test, evaluate and refine the framework and work together to develop training and use materials that meet the diverse needs of different users (a provisional tool is provided as Appendix 4).

Ultimately, the framework should help with silvicultural decision-making by facilitating classification of mature forest sites, and by identifying vegetation and underlying site and soil conditions. This will help better predict post-harvest vegetation development and competition potential. The ecological framework is currently being used to support a companion project, a digital compendium of vegetation management studies for HAP 2.0. This will allow us to relate, organize, and synthesize long-term studies, as well as identify knowledge gaps regarding vegetation management on particular site conditions. The framework should also help support HAP 2.0 partners in the development of recommendations for site-specific herbicide alternatives. Further work may include the use of remote sensing technology to identify sites with limited, or conversely, high vegetation competition potential.

Acknowledgements

This project was supported by the Canadian Wood Fibre Centre and the Great Lakes Forestry Centre of the Canadian Forest Service, Natural Resources Canada, through the “Developing Sustainable Fibre Solutions” program. It also received funding from Natural Resources Canada and the Canadian Forest Service Innovation Funds.

The proposed ecological framework is based on various Ontario, Quebec and Canadian National ecological classification systems and the authors’ experiences. We thank Jean-Pierre Saucier and Ken Baldwin for their initial input regarding the framework, and Lisa Venier, Roxanne Comeau, Holly Deighton and two anonymous reviewers for their input that substantially improved the manuscript.

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Appendices

Appendix 1. Scientific names, authorities, common English and French names and lifeforms of plant species included in this report. Nomenclature follows Baldwin et al., 2019a.

Table A1. List of tree species included in this report.

Scientific name	Authority	English name	French name	Life form
Abies balsamea	(Linnaeus) Miller	balsam fir	sapin baumier	coniferous tree
Acer rubrum	Linnaeus	red maple	érable rouge	broad-leaved tree
Acer saccharum	Marshall	sugar maple	érable à sucre	broad-leaved tree
Betula alleghaniensis	Britton	yellow birch	bouleau jaune	broad-leaved tree
Betula papyrifera	Marshall	paper birch	bouleau à papier	broad-leaved tree
Larix laricina	(Du Roi) K. Koch	tamarack	mélèze laricin	coniferous tree
Picea glauca	(Moench) Voss	white spruce	épinette blanche	coniferous tree
Picea mariana	(Miller) Britton, Sterns & Poggenburgh	black spruce	épinette noire	coniferous tree
Picea rubens	Sargent	red spruce	épinette rouge	coniferous tree
Pinus banksiana	Lambert	jack pine	pin gris	coniferous tree
Pinus resinosa	Aiton	red pine	pin rouge	coniferous tree
Pinus strobus	Linnaeus	eastern white pine	pin blanc	coniferous tree
Populus balsamifera	Linnaeus	balsam poplar	peuplier baumier	broad-leaved tree
Populus grandidentata	Michaux	large-toothed aspen	peuplier à grandes dents	broad-leaved tree
Populus tremuloides	Michaux	trembling aspen	peuplier faux-tremble	broad-leaved tree
Quercus rubra	Linnaeus	northern red oak	chêne rouge	broad-leaved tree
Thuja occidentalis	Linnaeus	eastern white cedar	thuya occidental	coniferous tree
Tsuga canadensis	(Linnaeus) Carrière	eastern hemlock	pruche du Canada	coniferous tree

Table A2. List of understory plant species included in this report.

Scientific name	Authority	Synonym	English name	French name	Life form
Acer pensylvanicum	Linnaeus		striped maple	érable de Pennsylvanie	deciduous shrub
Acer spicatum	Lamarck		mountain maple	érable à épis	deciduous shrub
Alnus incana ssp. *rugosa*	(Du Roi) R.T. Clausen	*Alnus rugosa*	speckled alder	aulne rugueux	deciduous shrub
Alnus viridis ssp. *crispa*	(Aiton) Turrill	*Alnus crispa*	American green alder	aulne crispé	deciduous shrub
Amelanchier sp.	Medikus		serviceberry	amélanchier	deciduous shrub
Aralia nudicaulis	Linnaeus		wild sarsaparilla	aralie à tige nue	forb
Arctostaphylos uva-ursi	(Linnaeus) Sprengel		common bearberry	raisin d'ours	evergreen shrub
Athyrium filix-femina	(Linnaeus) Roth ex Mertens		common lady fern	athyrie fougère-femelle	fern or fern-ally
Bazzania trilobata	(Linnaeus) S. Gray		three-lobed whipwort	bazzanie trilobée	hepatic
Carex sp.	Linnaeus		sedge	carex	graminoid
Chamaedaphne calyculata	(Linnaeus) Moench		leatherleaf	cassandre caliculé	evergreen shrub
Chamaenerion angustifolium	(Linnaeus) Scopoli	*Epilobium angustifolium*	fireweed	épilobe à feuilles étroites	forb
Cladina mitis	(Sandst.) Hustich		green reindeer lichen	cladine lisse	lichen
Cladina rangiferina	(Linnaeus) Nyl.		grey reindeer lichen	cladine rangifère	lichen
Cladina sp.	Nyl.		reindeer lichen	cladine	lichen
Cladina stellaris	(Opiz) Brodo		star-tipped reindeer lichen	cladine étoilée	lichen
Clintonia borealis	(Aiton) Rafinesque		yellow clintonia	clintonie boréale	forb
Comptonia peregrina	(Linnaeus) J.M. Coulter		sweet-fern	comptonie voyageuse	deciduous shrub
Coptis trifolia	(Linnaeus) Salisbury	*Coptis groenlandica*	goldthread	savoyane	forb
Cornus alternifolia	Linnaeus f.		alternate-leaved dogwood	cornouiller à feuilles alternes	deciduous shrub
Cornus canadensis	Linnaeus		bunchberry	quatre-temps	forb
Cornus sericea	Linnaeus	*Cornus stolonifera*	red-osier dogwood	cornouiller stolonifère	deciduous shrub
Corylus cornuta	Marshall		beaked hazelnut	noisetier à long bec	deciduous shrub
Dendrolycopodium obscurum	(Linnaeus) A. Haines	*Lycopodium obscurum*	flat-branched tree-clubmoss	lycopode obscur	fern or fern-ally
Dicranum sp.	Hedw.		broom moss	dicrane	moss
Diervilla lonicera	Miller		northern bush-honeysuckle	dièreville chèvrefeuille	deciduous shrub
Dryopteris spinulosa	(O.F. Müller) Watt		wood fern	dryoptère	fern or fern-ally
Equisetum sp.	Linnaeus		horsetail	prêle	fern or fern-ally

Scientific name	Authority	Synonym	English name	French name	Life form
Eurybia macrophylla	(Linnaeus) Cassini	*Aster macrophyllus*	large-leaved aster	aster à grandes feuilles	forb
Fragaria sp.	Linnaeus		strawberry	fraisier	forb
Galium sp.	Linnaeus		bedstraw	gaillet	forb
Gaultheria procumbens	Linnaeus		eastern teaberry	thé des bois	dwarf woody plant
Gramineae	various		grasses	graminées	graminoid
Gymnocarpium dryopteris	(Linnaeus) Newman	*Dryopteris disjuncta*	common oak fern	gymnocarpe fougère-du-chêne	fern or fern-ally
Hieracium sp.	Linnaeus		hawkweed	épervière	forb
Huperzia lucidula	(Michaux) Trevisan	*Lycopodium lucidulum*	shining firmoss	lycopode brillant	fern or fern-ally
Hylocomium splendens	(Hedw.) Schimp. in B.S.G.		stairstep moss	hylocomie brillante	moss
Ilex mucronata	(Linnaeus) M. Powell, V. Savolainen & S. Andrews	*Nemopanthus mucronatus*	mountain holly	némopanthe mucroné	deciduous shrub
Kalmia angustifolia	Linnaeus		sheep laurel	kalmia à feuilles étroites	evergreen shrub
Kalmia polifolia	Wangenheim		pale bog laurel	kalmia à feuilles d'andromède	dwarf woody plant
Linnaea borealis	Linnaeus		twinflower	linnée boréale	dwarf woody plant
Lonicera canadensis	Bartram ex Marshall		Canada fly-honeysuckle	chèvrefeuille du Canada	deciduous shrub
Lysimachia borealis	(Rafinesque) U. Manns & Anderberg	*Trientalis borealis*	northern starflower	trientale boréale	forb
Maianthemum canadense	Desfontaines		wild lily-of-the-valley	maïanthème du Canada	forb
Maianthemum racemosum	(Linnaeus) Link	*Smilacina racemosa*	large false Solomon's seal	smilacine à grappes	forb
Maianthemum trifolium	(Linnaeus) Sloboda	*Smilacina trifolia*	three-leaved false Solomon's seal	smilacine trifoliée	forb
Medeola virginiana	Linnaeus		Indian cucumber-root	médéole de Virginie	forb
Mitella nuda	Linnaeus		naked mitrewort	mitrelle nue	forb
Mnium sp.	Hedw.		leafy moss	mnie	moss
Oclemena acuminata	(Michaux) Greene	*Aster acuminatus*	whorled wood aster	aster acuminé	forb
Osmunda claytoniana	Linnaeus		interrupted fern	osmonde de Clayton	fern or fern-ally
Osmundastrum cinnamomeum	(Linnaeus) C. Presl	*Osmunda cinnamomea*	cinnamon fern	osmonde cannelle	fern or fern-ally
Oxalis montana	Rafinesque		common wood-sorrel	oxalide de montagne	forb
Phegopteris connectilis	(Michaux) Watt	*Dryopteris phegopteris*	northern beech fern	phégoptère du hêtre	fern or fern-ally

Scientific name	Authority	Synonym	English name	French name	Life form
Pleurozium schreberi	(Brid.) Mitt.		red-stemmed feathermoss	pleurozie dorée	moss
Polygonatum pubescens	(Willdenow) Pursh		hairy Solomon's seal	sceau-de-Salomon pubescent	forb
Polytrichum sp.	Hedw.		haircap moss	polytric	moss
Prunus pensylvanica	Linnaeus f.		pin cherry	cerisier de Pennsylvanie	deciduous shrub
Prunus virginiana	Linnaeus		chokecherry	cerisier de Virginie	deciduous shrub
Pteridium aquilinum	(Linnaeus) Kuhn		bracken fern	fougère-aigle	fern or fern-ally
Ptilium crista-castrensis	(Hedw.) De Not.		knight's plume moss	hypne plumeuse	moss
Pyrola sp.	Linnaeus		pyrola	pyrole	forb
Rhododendron groenlandicum	(Oeder) Kron & Judd	*Ledum groenlandicum*	common Labrador tea	thé du Labrador	evergreen shrub
Ribes glandulosum	Grauer		skunk currant	gadellier glanduleux	deciduous shrub
Rosa acicularis	Lindley		prickly rose	rosier aciculaire	deciduous shrub
Rubus idaeus	Linnaeus		red raspberry	framboisier rouge	deciduous shrub
Rubus pubescens	Rafinesque		dwarf raspberry	ronce pubescente	forb
Salix sp.	Linnaeus		willow	saule	deciduous shrub
Sambucus racemosa	(Michaux) Hultén	*Sambucus pubens*	red elderberry	sureau à grappes	deciduous shrub
Sorbus americana	Marshall		American mountain-ash	sorbier d'Amérique	deciduous shrub
Sorbus decora	(Sargent) C.K. Schneider		showy mountain-ash	sorbier plaisant	deciduous shrub
Sphagnum sp.	Linnaeus		peat moss	sphaigne	moss
Streptopus lanceolatus	(Aiton) Reveal	*Streptopus roseus*	rose twisted-stalk	streptope rose	forb
Taxus canadensis	Marshall		Canada yew	if du Canada	evergreen shrub
Tiarella cordifolia	Linnaeus		heart-leaved foamflower	tiarelle cordifoliée	forb
Vaccinium angustifolium	Aiton		early lowbush blueberry	bleuet à feuilles étroites	evergreen shrub
Vaccinium myrtilloides	Michaux		velvet-leaved blueberry	bleuet fausse-myrtille	evergreen shrub
Viburnum lantanoides	Michaux	*Viburnum alnifolium*	hobblebush	viorne bois-d'orignal	deciduous shrub
Viburnum nudum var. *cassinoides*	(Linnaeus) Torrey & A. Gray	*Viburnum cassinoides*	wild raisin	viorne cassinoïde	deciduous shrub
Viola sp.	Linnaeus		violet	violette	forb

Appendix 2. Conceptual distributions of Quebec indicator species groups along gradients of site drainage and relative richness (adapted from Ministère des Ressources Naturelles, 2013a). Codes and species included in indicator species groups are provided in Figure 3.

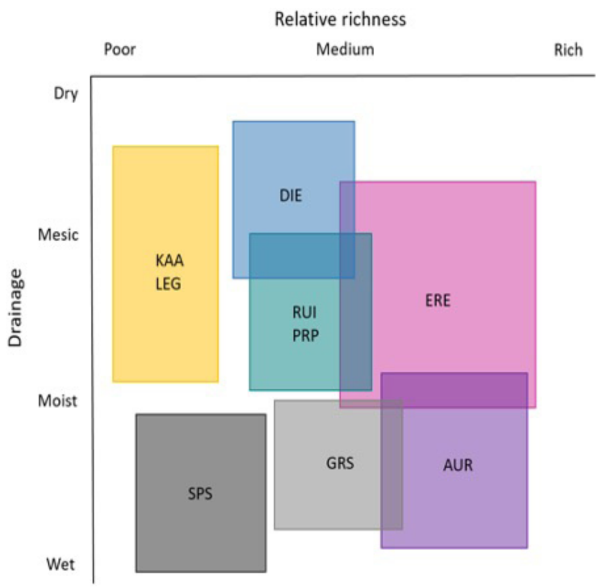

Figure A1. Distribution of Quebec indicator species groups of perturbation arranged along gradients of site drainage and relative richness.

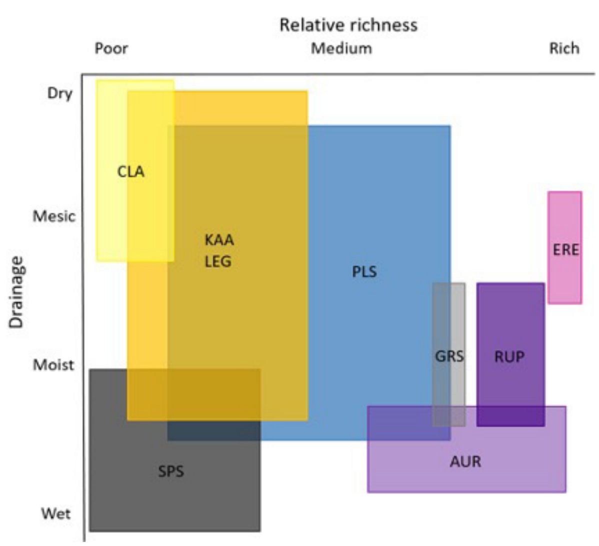

Figure A2. Distribution of Quebec indicator species groups for boreal zone *Picea mariana*, *Pinus banksiana*, or *Picea mariana* with *Abies balsamea* forests arranged along gradients of site drainage and relative richness.

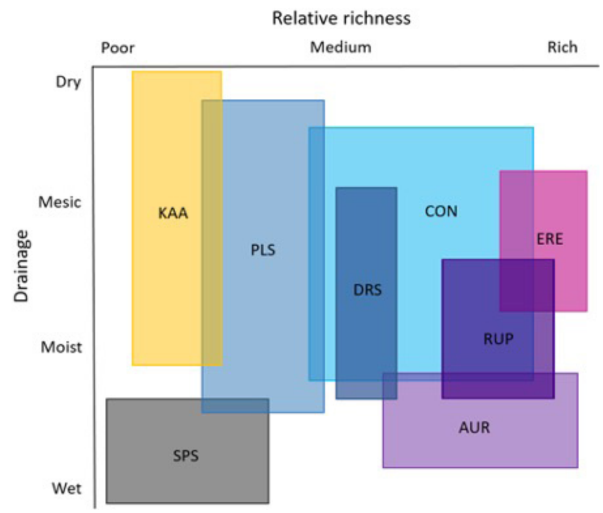

Figure A3. Distribution of Quebec indicator species groups for boreal zone forests of *Abies balsamea* and *Picea glauca* with *Betula papyrifera* and *Populus* spp. arranged along gradients of site drainage and relative richness.

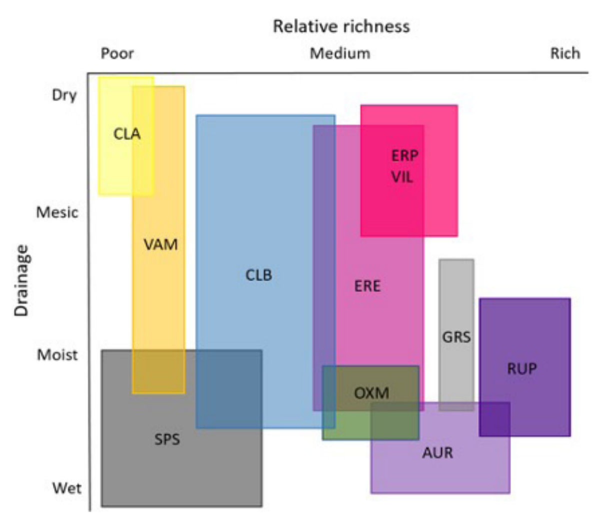

Figure A4. Distribution of Quebec indicator species groups for temperate zone mixedwood *Betula alleghaniensis*, *Pinus strobus* or *Tsuga heterophylla* forests arranged along gradients of site drainage and relative richness.

Appendix 3. HAP 2.0 Site and substrate classes as used in Table 3, including translations to Quebec and Ontario provincial codes, where relevant. Note: - = not applicable.

Table A3. Site and substrate classes and translations to Ontario and Quebec codes.

Variable	Class		Ontario	Quebec
Mode of deposition	bedrock (includes boulder pavement)		BR	substratum rocheux (R)
	morainal/till		M, T	dépôts glaciaires (1)
	glaciofluvial (includes fluvial)		glaciofluvial (GF) fluvial (F)	dépôts fluvioglaciaires (2) dépôts fluviatiles (3)
	lacustrine (includes glaciolacustrine)		lacustrine (L)	dépôts lacustres (4)
	marine (includes glaciomarine)		-	dépôts marins (5) dépôts littoraux marins (6)
	organic		organic (O)	dépôts organiques (7)
	colluvium		colluvium (C)	dépôts de pentes et d'altération (8)
	eolian		eolien (E)	dépôts éoliens (9)
Slope position	crest		crest (1)	sommet arrondi (3)
	upper		upper slope (2)	haut de pente (4)
	mid		middle slope (3)	mi-pente (5) escarpement (2)
	lower		lower slope (4) toe slope (5)	bas de pente (7)
	depression		depression (6)	dépression ouverte (8) dépression fermée (9)
	level		level (7)	terrain plat (0) replat (6)
Slope gradient (%)	level	<4%	-	-
	gentle	4-10%	-	-
	moderate	11-19%	-	-
	moderately steep	20-34%	-	-
	steep	35-65%	-	-
	very steep	66-100%	-	-
Coarse fragment content (%)	low	0-15%	-	-
	moderate	16-35%	-	-
	high	≥35%	-	-

Variable	Class		Ontario	Quebec
Substrate depth	shallow	<30 cm	-	-
	moderately deep	30-120 cm	-	-
	deep	≥120 cm	-	-
Texture class	coarse sandy		very coarse sand (vcS), coarse sand (cS), medium sand (mS), loamy very coarse sand (LvcS), loamy coarse sand (LcS), loamy medium sand (LmS)	sable très grossier (Stg), sable grossier (Sg), sable moyen (Sm), sable très grossier loameux (StgL), sable grossier loameux (SgL), sable moyen loameux (SmL)
	fine sandy		fine sand (fS), loamy fine sand (LfS)	sable très fin (Stf), sable fin (Sf), sable fin loameux (SfL)
	coarse loamy		silty very coarse sand (SivcS), silty coarse sand (SicS), silty medium sand (SimS), silty fine sand (SifS), very coarse sandy loam (vcSL), medium sandy loam (mSL), fine sandy loam (fSL), very fine sandy loam (vfSL), loamy very fine sand (LvfS), very fine sand (vfS)	loam (L), loam sableux très grossier (LStg), loam sableux grossier (LSg), loam sableux moyen (LSm), loam sableux fin (LSf), loam sableux très fin (LStf), sable très fin loameux (StfL)
	silty		silt (Si) silt loam (SiL)	limon, loam limoneux
	fine loamy		clay loam (CL), silty clay loam (SiCL), sandy clay loam (SCL)	loam argileux, loam limon-argileux, loam sablo-argileux
	clayey		clay (C), silty clay (SiC), sandy clay (SC)	argile, argile limoneuse, argile sableuse
Drainage class	rapid		very rapid	excessif (0)
			rapid	rapide (1)
	well		well	bon (2)
	moderately well		moderately well	modéré (3)
	imperfect		imperfect	imparfait (4)
	poor		poor	mauvais (5)
			very poor	très mauvais (6)
Humus form	mor (including fibrimor, humimor)		mor	mor
	peatymor		peatymor	mor tourbeux / tourbe
	moder		moder	moder
	mull		mull	mull
	organic		organic	sol organique
	not applicable		not applicable	absence d'humus ou humus très perturbé

Variable	Class	Ontario	Quebec
Soil moisture regime	dry	very dry (Θ), dry (0)	xérique: 00, 10, 11, 16
	mesic	moderately fresh (1) fresh (2) very fresh (3)	mésique: 20, 21, 30, 32, 33, 34
	moist	moderately moist (4) moist (5) very moist (6)	subhydrique: 31, 40, 41, 42, 43, 44
	wet	moderately wet (7) wet (8) very wet (9)	hydrique: 50, 51, 52, 53, 54 60, 61, 62, 63
Soil nutrient regime	poor	poor	pauvre
	medium	medium	moyen
	rich	rich	riche

Appendix 4. Cheat sheet for applying the first approximation of the HAP Ecological Framework to classify sites.

HAP Ecological Framework: ecological & silvicultural site classification tool to support vegetation management decisions

This framework is intended to be applied to ground plot data collected in relatively homogenous forests. If the vegetation, topographic or other site or soil characteristics change substantially over a small area, the area is best considered as multiple units before trying to apply the framework. For classification, plots would typically be about 10m x 10m in size in more homogenous, northern, boreal forests, but larger (e.g., 20m x 20m) in more heterogeneous, southern, temperate forests. Although the framework is presented as combinations of overstory and understory (vegetation) classes, the classes reflect climate (more boreal vs. more temperate) and site and soil conditions. All of these variables are important to consider in finding the best fit.

START HERE How to use the Ecological Framework to classify a plot:

1. Within northeastern Ontario, consider the stand location. Is it more boreal (Ecoregion 3E), consisting of more boreal species, or transitioning to more temperate, with more temperate species (Ecoregions 4E or 5E; see Fig. 1, Table 1)?

2. Identify the overstory class in Table 1 that best fits the tree composition and cover in the plot (estimate % cover by species).

3. Evaluate the slope position, gradient and substrate variables in Table 2 and consider how these would affect the overall site moisture and nutrients and position of the plot on the conceptual soil moisture x soil nutrient grid of Fig. 2.

4. (continue on reverse side)

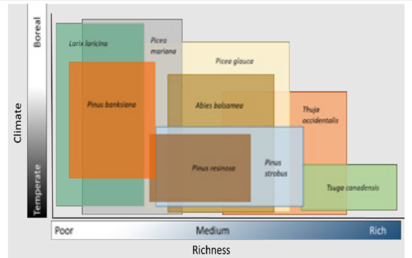

Figure 1. Conifer species arranged along gradients of climate and site richness (modified From Ministère des Ressources Naturelles 2013a).

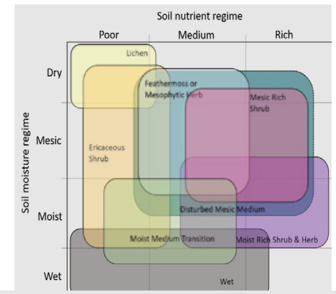

Figure 2. HAP understory classes arranged along gradients of soil moisture and soil nutrient regimes.

Table 1. HAP overstory classes and criteria, grading from more boreal (white boxes), to more temperate (black boxes).

Overstory Class	Criteria
1. Trembling aspen, Balsam poplar, Large-toothed aspen Hardwood & Mixedwood	Aspens, Poplar + Paper birch ≥25%; Aspen + Poplar spp.> Paper birch; <25% conifer; <10% temperate spp.
2. Paper birch Hardwood & Hardwood-dominated Mixedwood	Paper birch + Trembling aspen ≥50%; Paper birch > Poplar spp.; <50% conifer; <10% temperate spp.
3. Balsam fir &/or **White spruce**-dominated Conifer & Mixedwood	Balsam fir + White spruce > Jack pine + Black spruce; <50% hardwoods; <10% temperate spp., in mixes with Black spruce, fir ≥35%
4. Jack pine, Black spruce &/or **Tamarack** Conifer	Any of Jack pine, Black spruce &/or Tamarack dominant; Conifers ≥75%; <25% hardwood; <10% temperate spp., <35% Balsam fir
5. White &/or Red pine Conifer & Mixedwood	White + Red pine ≥30%; <10% Eastern white cedar, <30% Eastern hemlock
6. Eastern white cedar Conifer & Mixedwood	Eastern white cedar ≥10%; Eastern hemlock <30%
7. Eastern hemlock Conifer & Mixedwood	Eastern hemlock ≥30%
8. Yellow birch &/or Red maple Mixedwood	Yellow birch + Red maple ≥25%; <30% White + Red pine; <10% Eastern white cedar; <30% Eastern hemlock

Table 2. Site and substrate characteristics for HAP understory classes.

Site or substrate variable	A. Lichen	B. Ericaceous Shrub	C. Feathermoss or Mesophytic Herb	D. Disturbed Mesic to Moist, Medium to Rich	E. Mesic Rich Shrub	F. Moist Rich Shrub and Herb	G. Moist Medium Transition	H. Wet
Mode of deposition	bedrock; morainal/till; glaciofluvial	morainal/till; glaciofluvial	morainal/till; glaciofluvial	morainal/till; glaciofluvial; lacustrine	morainal/till; glaciofluvial; lacustrine	glaciofluvial; lacustrine	glaciofluvial; lacustrine; organic	organic
Slope position	crest; upper; mid; level	upper; mid; lower; level	upper; mid; level	mid; lower; level	mid; lower; level	lower; toe; level	lower; toe; level	level; depression
Slope gradient	level to mod.	level to mod. steep	level to steep	level to mod. steep	level to mod.	level to mod.	level to mod.	level
Coarse fragment content	low to high	low to high	low to mod.	low to mod.	low to mod.	low	low	low
Substrate depth	depends on deposition	mod. deep to deep	mod. deep to deep	any	mod. deep to deep	mod. deep to deep	deep	deep peat deposit
Texture class	coarse sandy to coarse loamy	coarse sandy to coarse loamy	coarse loamy to fine loamy	coarse loamy to fine loamy	coarse loamy to fine loamy; (clay underlay)	coarse loamy to fine loamy; (clay underlay)	fine loamy to clayey	organic (commonly Of horizons)
Drainage	rapid	well to imperfect	well to mod. well	well to imperfect	well to imperfect	mod. well to imperfect	imperfect to poor	poor
Humus form	mor (fibrimor)	mor (fibrimor to humimor)	mor (fibrimor to humimor)	mor; moder	mor (humimor); moder	moder; mull	mor (humimor); peatymor; moder	peatymor; organic
Soil moisture regime	dry	dry to moist	mesic	mesic to moist	mesic to moist	moist	moist to wet	wet
Soil nutrient regime	poor	poor	medium	medium to rich	medium to rich	medium to rich	poor to medium	poor to medium

How to use the Ecological Framework to classify a plot (continued)

4. Evaluate understory species composition and abundance. Using the indicator species lists for more boreal and more temperate sites in Table 3, determine the understory class or classes that best fit(s) the entire suite of species in the understory.

5. Using the site and substrate information evaluated in Step 3 (Table 2), and the understory vegetation in Step 4, confirm the understory class that best fits the site.

6. Check that the overstory class (Step 2) and understory class (Steps 3-5) occur together in Table 4, if not, re-consider. Assessment may still be valid, but the combination is not common.

Table 4. Likely co-occurrence of overstory (rows) and understory (columns) classes.

O/s x U/s	A	B	C	D	E	F	G	H
1								
2								
3								
4								
5								
6								
7								
8								

Table 3. Indicator species of each understory class (A-H) on more boreal or more temperate sites.

Understory Class	Indicator species on BOREAL sites		Indicator species on TEMPERATE sites	
A. Lichen	*Cladina* sp.	reindeer lichen	*Vaccinium angustifolium*	early lowbush blueberry
			Gaultheria procumbens	eastern teaberry
			Dicranum sp.	broom moss
			Cladina sp.	reindeer lichen
B. Ericaceous Shrub	*Kalmia angustifolia*	sheep laurel	*Kalmia angustifolia*	sheep laurel
	*Rhododendron groenlandicum**	common Labrador tea*	*Vaccinium myrtilloides*	velvet-leaved blueberry
	Vaccinium angustifolium	early lowbush blueberry	*Linnaea borealis*	twinflower
	Vaccinium myrtilloides	velvet-leaved blueberry		
C. Feathermoss or mesophytic herb	*Alnus viridis* ssp. *crispa*	American green alder	*Amelanchier* sp.	serviceberry
	Amelanchier sp.	serviceberry	*Diervilla lonicera*	northern bush-honeysuckle
	Diervilla lonicera	northern bush-honeysuckle	*Sorbus americana*	American mountain-ash
	*Ilex mucronata***	mountain holly**	*Viburnum nudum* var. *cassinoides***	wild raisin**
	Viburnum nudum var. *cassinoides***	wild raisin**	*Clintonia borealis*	yellow clintonia
	Linnaea borealis	twinflower	*Coptis trifolia*	goldthread
	Aralia nudicaulis	wild sarsaparilla	*Cornus canadensis*	bunchberry
	Clintonia borealis	yellow clintonia	*Eurybia macrophylla*	large-leaved aster
	Coptis trifolia	goldthread	*Lysimachia borealis*	northern starflower
	Cornus canadensis	bunchberry	*Maianthemum canadense*	wild lily-of-the-valley
	Eurybia macrophylla	large-leaved aster	*Oxalis montana*	common wood-sorrel
	Lysimachia borealis	northern starflower	*Pteridium aquilinum*	bracken fern
	Maianthemum canadense	wild lily-of-the-valley	*Hylocomium splendens**	stairstep moss*
	Oxalis montana	common wood-sorrel	*Pleurozium schreberi**	red-stemmed feathermoss*
	Pyrola sp.	pyrola	*Polytrichum* sp.*	haircap moss*
	Dryopteris spinulosa	wood fern	*Bazzania trilobata**	three-lobed whipwort*
	Pteridium aquilinum	bracken fern		
	Dicranum sp.*	broom moss*		
	*Hylocomium splendens**	stairstep moss*		
	*Pleurozium schreberi**	red-stemmed feathermoss*		
	*Ptilium crista-castrensis**	knight's plume moss*		
D. Disturbed Mesic to Moist, Medium to Rich	*Prunus pensylvanica*	pin cherry	*Rubus idaeus*	red raspberry
	Rubus idaeus	red raspberry		
	Chamaenerion angustifolium	fireweed		
	Fragaria sp.	strawberry		
	Hieracium sp.	hawkweed		
E. Mesic Rich Shrub	*Acer spicatum*	mountain maple	*Acer pensylvanicum*	striped maple
	Corylus cornuta	beaked hazelnut	*Acer spicatum*	mountain maple
	Sambucus racemosa	red elderberry	*Corylus cornuta*	beaked hazelnut
	Taxus canadensis	Canada yew	*Lonicera canadensis*	Canada fly-honeysuckle
			Viburnum lantanoides	hobblebush
			Taxus canadensis	Canada yew
			Aralia nudicaulis	wild sarsaparilla
			Maianthemum racemosum	large false Solomon's seal
			Medeola virginiana	Indian cucumber-root
			Polygonatum pubescens	hairy Solomon's seal
			Streptopus lanceolatus	rose twisted-stalk
			Dendrolycopodium obscurum	flat-branched tree-clubmoss
			Dryopteris spinulosa	wood fern
			Huperzia lucidula	shining firmoss
F. Moist Rich Shrub and Herb	*Alnus incana* ssp. *rugosa**	speckled alder*	*Alnus incana* ssp. *rugosa**	speckled alder*
	Ribes glandulosum	skunk currant	*Cornus alternifolia*	alternate-leaved dogwood
	Galium sp.	bedstraw	*Oclemena acuminata*	whorled wood aster
	Mitella nuda	naked mitrewort	*Rubus pubescens*	dwarf raspberry
	Rubus pubescens	dwarf raspberry	*Tiarella cordifolia*	heart-leaved foamflower
	Athyrium filix-femina	common lady fern	*Viola* sp.	violet
	Equisetum sp.*	horsetail*	*Athyrium filix-femina*	common lady fern
	Gymnocarpium dryopteris	common oak fern	*Gymnocarpium dryopteris*	common oak fern
	Osmunda claytoniana	interrupted fern	*Osmunda claytoniana*	interrupted fern
	Osmundastrum cinnamomeum	cinnamon fern	*Osmundastrum cinnamomeum**	cinnamon fern*
	Mnium sp.	leafy moss	*Phegopteris connectilis*	northern beech fern
			Mnium sp.	leafy moss
G. Moist Medium Transition	*Alnus incana* ssp. *rugosa**	speckled alder*	*Alnus incana* ssp. *rugosa**	speckled alder*
	*Rhododendron groenlandicum**	common Labrador tea*	*Ilex mucronata**	mountain holly*
	Equisetum sp.*	horsetail*	*Osmundastrum cinnamomeum**	cinnamon fern*
	Dicranum sp.*	broom moss*	*Hylocomium splendens**	stairstep moss*
	*Pleurozium schreberi**	red-stemmed feathermoss*	*Pleurozium schreberi**	red-stemmed feathermoss*
	*Ptilium crista-castrensis**	knight's plume moss*	*Polytrichum* sp.*	haircap moss*
	Sphagnum sp.*	peat moss*	*Sphagnum* sp.*	peat moss*
			*Bazzania trilobata**	three-lobed whipwort*
H. Wet	*Chamaedaphne calyculata*	leatherleaf	*Ilex mucronata**	mountain holly*
	Kalmia polifolia	pale bog laurel	*Salix* sp.	willow
	Maianthemum trifolium	three-leaved false Solomon's seal	*Carex* sp.	sedge
	Carex sp.	sedge	*Gramineae*	grasses
	Gramineae	grasses	*Sphagnum* sp.*	peat moss*
	Sphagnum sp.*	peat moss*		

*indicative of multiple groups

**may be less important in NE Ontario; requires further review