High Production Forestry

Phase 1 - Discussion Paper

February 2020

NOVA SCOTIA

High Production Forestry - Executive Summary

High Production Forests within Sustainable Forest Management in Nova Scotia

"Sustainable Forest Management (SFM) maintains and enhances the long-term health of forest ecosystems for the benefit of all living things while providing environmental, economic, social, and cultural opportunities for present and future generations" (Natural Resources Canada, 2008)[1]. The difficulty in applying SFM, particularly on public land, is in satisfying the diverse, and often conflicting, expectations society has for what is a finite amount of forested land; society values economic development but also old growth forest, it values species for hunting but also endangered species, and it values recreational opportunity but also employment opportunity (Davis et al. 2001)[2]. One approach to satisfying these demands is to divide the land into zones, each managed to provide a specific set of desired values. Triad zoning exemplifies this concept (Seymour and Hunter 1992[3], Lahey 2018[4]) and divides the forest into 3 zones; a conservation zone with no resource extraction (for conservation of biodiversity and natural processes); a highly productive zone supporting timber production; and an ecological matrix zone comprising the majority of the land base where there is a mix of biodiversity conservation and timber production.

The Government of Nova Scotia has committed to implementing a triad system on public land, and work is underway to determine how this will be designed and implemented (L&F, 2018)[5]. The purpose of this Discussion Paper is to share information about and elicit feedback on the proposed definition of High Production Forestry and the selection criteria and ranking methods that could be used to identify HPF area on Crown land. It is important to note that the actual selection of sites will not take place until the second phase of this project which is anticipated to begin in 2020.

Role of High Production Forest

High Production Forests (HPF) are an important zone in the triad system. The production of primary and secondary forest products supports the livelihood of many Nova Scotians and, in some communities, is a significant economic driver that supports many direct and indirect jobs and services. The high yields expected from HPF will help ensure an adequate supply of timber to support the economy and employment and will partly offset the loss of timber supply from reduced management intensity within the ecological matrix zone. Further, the Lahey (2018) report notes that "expanding the area of production forestry, as well as improving harvest scheduling and silvicultural practices to ensure high yields, is arguably the only strategy that would allow harvests to be increased substantially at some time in the future" [p. 66 Addendum].

[1] Natural Resources Canada. (2008). A Vision for Canada's Forests: 2008 and Beyond. 16 pp

[2] Davis, L., N. Johnson, P. Bettinger, and T. Howard. (2001). Forest Management to Sustain Ecological, Economic, and Social Values. McGraw Hill, Boston. 804 pp.

[3] Seymour, R.S., and Hunter, M.L. (1999). Principles of ecological forestry. Maintaining Biodiversity in Forest Ecosystems. Ch. 2: 22–61.

[4] Lahey, W. (2018). An Independent Review of Forest Practices in Nova Scotia: Executive Summary, Conclusions and Recommendations. 70 pp.

[5] Nova Scotia Department of Lands and Forestry (L&F). (2018). Government Response to the Independent Review of Forest Practices in Nova Scotia. 6 pp.

Practices in High Production Forest

In practice, realizing and sustaining high timber yields in the HPF zone involves the use of intensive silvicultural practices, comparable to an agricultural model but with longer crop rotation. In Nova Scotia, these may include regimes comprising mechanical site preparation prior to planting of fast-growing softwood tree species (Picea spp. (otherwise known as spruce)), followed by competition control with herbicides and thinning to lessen natural vegetative competition for sun, water and nutrients. The use of fertilizer, a common practice in agriculture, may be included in the silviculture regime to sustain and/or increase site productivity over the course of a timber rotation. The resulting increase of crop tree growth is expected to yield high volumes of timber and high value forest products in a shortened timeframe.

Harvesting methods in the HPF zone are expected to include commercial thinning and clearcutting, which result in even-aged stand structures. The harvest prescriptions and resulting stand structures in the HPF zone differ from those in the ecological matrix zone where irregular shelterwood and selection harvests are expected to be employed as the primary harvest methods to produce timber, but more importantly to maintain or create more complex stand structures comprising late successional tree species, biological legacies, and multiple age classes, all of which serve the objectives for the matrix forest (Davis et al. 2001[2]; Nyland 2002[6]) – to prioritize biodiversity.

Selection of High Production Forest Areas

While there are many criteria that can be considered in selecting areas appropriate for HPF, based on our analysis, three key criteria are being proposed for consideration in the establishment of the HPF zone of the triad in Nova Scotia. First and foremost, the HPF zones should include land capable of supporting rapid tree growth, and thus must have the fertility, and drainage characteristics conducive to such growth. Second, the sites should lend economic efficiency, such that wood procurement (including extraction, transport, and other production costs) and processing to finished product is profitable. Situating HPF near established wood processing facilities (e.g. sawmills) will reduce the transportation costs thereby contributing to economic efficiency. Third, HPF should be situated with consideration of existing land use. First consideration should be given to sites already converted from natural forest (e.g., abandoned agricultural fields or existing tree plantations) or other areas already anthropogenically (human) modified, wherever possible. Such sites are typically productive, accessible and in a landscape with existing infrastructure and road networks, thus, they do not require converting from undeveloped or natural forest area which is more challenging both from a cost and social acceptability standpoint.

The proposed strategy to locate the HPF zone would thus seek to identify area that meets the productivity, distance and existing land use criteria while avoiding conservation areas, special habitats and a host of other environmentally sensitive areas. Limited area across Nova Scotia Crown land meets these criteria, and thus, HPF would be the smallest of the three triad zones.

Analysis that demonstrates proposed methods and ranking using the proposed selection criteria found that up to approximately 18.2% of Crown would be technically suitable for high production forest management, prior to any other considerations. Provincially, this represents 6% of the total landbase (333,000 hectares of 5.5 million hectares in province).

[6] Nyland, R. (2002). Silviculture: Concepts and Applications. Waveland Press, Illinois. 682 pp

Table of Contents

Draft Definition of High Production Forestry in Nova Scotia

High Production Forestry in the Triad Context

High Production Forestry (HPF) is one of three distinct management zones (aka "legs") within an overall balanced approach to sustainable forest management (SFM) known as the triad concept[7]. The other two zones of the triad include (1) conservation and the (2) ecological matrix. The conservation zone serves as a benchmark of ecological integrity, biodiversity, and natural processes. The ecological matrix zone ("the Matrix") has the goal of sustaining ecosystem condition and function as a priority, but where some timber harvesting can occur. The ability to apply HPF ultimately results in higher forest product yields being derived from a relatively small portion of the landbase.

The HPF model is comparable to farming as the land is intensively managed in order to increase the quantity and quality of a refined set of products over a specified timeline. HPF areas provide some biodiversity values however the primary objective is the production of forest products. The premise of the triad concept is that all three zones work together to achieve SFM.

High Production Forestry Basic Principles

Yield

HPF requires detailed planning at the site level (prior to harvest of existing stands) to facilitate timely site preparation and planting following harvest, using improved seedling stock[8] of native and non-invasive, non-native softwood species matched to site conditions.

Achieving and sustaining high yields on the resulting plantations is expected to require the application of approved herbicides to control natural vegetative competition during plantation establishment phase (0 – 5 years) to prevent growth setbacks and/or mortality of seedlings. Fertilizer is another tool which may be required to sustain optimal growing conditions and prevent long-term site degradation through nutrients found in timber products being removed from the site after harvest.

Rotations are expected to be short (30-45 years) compared with those in natural forests and will be based on producing high value timber (such as spruce saw timber) during commercial thinnings and clearcut harvest interventions.

HPF plantation yields can be expected to produce growth rates 2 to 4m^3/ha/yr greater than those typical in unmanaged natural stands (Appendix A) and would be expected to equal or exceed 6 m^3/ha/yr within the HPF zone.

Outcomes-Based Forestry

Outcomes-Based Forestry for Crown land forest management is being developed concurrently with HPF site ranking/selection. Within an outcomes-based system, so long as outcomes related to HPF are met (i.e. milestones to show growth and yield projections are on track), the methods used to achieve the outcome, so long as they are ecologically and legally acceptable, do not need to be prescribed explicitly to forest managers. The Outcomes Based Forestry system is still under development. However, to ensure wood supply needs are met for the HPF zone, minimum growth and yield targets and achieving free-to-grow status by a certain age are likely to be required outcomes.

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[7] Seymour, R.S., and Hunter, M.L. (1999). Principles of ecological forestry. Maintaining Biodiversity in Forest Ecosystems. Ch. 2: 22–61.

[8] Nova Scotia has had a tree improvement program in place for over 40 years conducting tree breeding, selection, and testing which results in genetically improved seedlings but does not involve genetic modification.

Relationship with Existing Regulations

Land zoned as HPF will have the primary goal of producing high-value wood products in the most economical way to meet societal needs for forest products. The HPF model is comparable to agriculture, as the land is intensively managed in order to increase the quantity and quality of a refined set of products over a specified timeline. Existing regulations, policies and guidelines, such as the *Wildlife Habitat and Watercourses Protection (WHWP) Regulations*, will still apply.

Key Assumptions for the HPF Zone

There are assumptions required to be made up-front with long-term forest management planning in order to assess potential outcomes of a HPF zone of the triad.

The first assumption is related to forest product market demand. Currently, highest value softwood forest product markets in Nova Scotia are spruce sawlogs and studwood (i.e. saw timber or sawables). As such, HPF is being designed to produce high yields of spruce saw timber products. Markets can change over time, and if the market demand shifts from spruce sawlogs and studwood to another species/product, HPF species strategies may need to be adjusted to reflect those changes. Other high value products including hardwood and pine logs are expected to be produced within the ecological matrix zone.

The second assumption is the expansion of acceptable silvicultural tools and practices on Crown land designated as HPF to include the use of herbicides, fertilizers and non-native spruce species in the establishment and maintenance of highly productive plantations.

Herbicide use on Crown land for forest management has not been a practice since 2010, nor is herbicide application a funded silviculture treatment by the Province of Nova Scotia. Fertilizers are not currently widely used in Nova Scotia for forest management, but much like in agriculture, may be required to maintain and enhance site productivity. Non-native species are not currently used to establish plantations on Crown land, however seed orchards of improved breeding stock of non- native species (Norway spruce) are currently available in the province to produce seedlings. This analysis currently assumes that herbicide, fertilizers and non-native species will be available tools in the HPF zone, however the extent of their use will be determined during Phase 2 when individual sites are selected.

With respect to assumptions around potential climate change impacts on the forest, elevated temperatures and altered precipitation regimes have the capacity to shift the geographic ranges and growth rates of tree species. The warmer climate and higher atmospheric concentrations of carbon dioxide (CO^2) may benefit tree growth and forest productivity in plantations. However, reduced precipitation during the longer growing seasons and the increasing frequency and severity of natural disturbance events like storms, forest pest outbreaks, and freeze-thaw cycles will continue to have significant adverse effects on Nova Scotia's natural forests and plantations alike. A commonality among all potential impacts of climate change on forest ecosystems is a high degree of uncertainty. As these changes are realized, HPF strategies will be adapted if needed to continue producing high timber yields.

Selection of HPF Sites

The identification of sites for HPF is vital to a successful triad system. The following applies proposed methods of selection of HPF sites based on 1) Suitable Landbase, 2) Analysis Framework, 3) Proposed Selection Criteria, 4) Proposed Ranking, and 5) Ranking Results.

Suitable Landbase

The scope of the analysis included all provincially owned land, referred to as "Crown" land within the context of this report. Areas that are converted to a non-forestry use or non-natural state were removed from the land-base considered under triad zoning (Table 1). This leaves 1,824,000 hectares to be categorized within the triad.

Table 1. Summary of areas considered outside of the scope of the three triad zones.

	Landbase Category	Area (000's ha)
	Gross Crown Landbase (Forested and Non-Forested)	1,854
Exclusions from Triad	Anthropogenic Non-Vegetated[1]	14
	Converted (Anthropogenic Vegetated)[2]	1.5
	Roads	20
	Triad Total Landbase (TLB)	**1,824**

[1] Urban, miscellaneous, sanitary landfill, gravel pit, pipeline corridor, powerline corridor, road corridor, rail corridor.
[2] Conversion originating from human activity while maintaining vegetative cover. Includes Christmas trees, seed orchard & seed production areas, blueberries.

The conservation zone is composed of areas that have no active forest resource extraction (Table 2). This includes areas protected by official designation (wilderness areas, nature reserves, parks, etc.) as well as proposed protected areas that have not been designated. In addition to protected areas, policies prohibit all management activities in old growth forests, so these are also considered as part of the conservation zone within the triad.

The ecological matrix zone is composed of areas suitable and eligible for timber production but subject to policy and operational constraints. For the purpose of this project analysis, in addition to policy and operational constraints, an ecosite-level attribute assessment was conducted to remove sensitive and low productivity ecosites from HPF consideration but allow them to be managed within the matrix. Marginal ecosites (AC6, AC7, lower fertility AC10 & AC11) were also removed from HPF consideration because of their low productivity and moved to the matrix. All tolerant hardwood sites, plus rich sites with current mixedwood or intolerant hardwood cover, were excluded from HPF consideration to limit negative biodiversity impacts associated with conversion to softwood forests. However, medium fertility sites with current mixedwood or intolerant hardwood cover were considered eligible for HPF since these sites typically succeed to or support a high percentage of softwood cover.

Table 2. Categorization of provincially-owned land considered part of the triad into Conservation, Matrix, or High Production.

Triad Zone	Landbase Category	Area (000's ha)	
		nTLB[1]	% of TLB
Conservation	Existing & Proposed Protected	611	33.5
	Old Forest Policy[2]	19	1.0
	Total	**630**	**34.5**
Ecological Matrix	Non-Forested Vegetated[3]	146	8.0
	Naturally Non-Vegetated[4]	7.6	0.4
	Regional Crown Exclusions[5]	34	1.9
	Wildlife Habitat Buffers[6]	48	2.6
	Wildlife Special Management Practice Zones[7]	41	2.3
	Watercourse Buffers[8]	41	2.3
	Inoperable/Subjective Removals[9]	42	2.3
	Rare/High Landuse Pressure Ecosections[10]	41	2.3
	Sensitive/Low Productivity Ecosites[11]	105	5.8
	Marginal Productivity Sites unsuitable for HPF[12]	261	14.3
	Tolerant Hardwood & Mixedwood / Intolerant Hardwood on Rich Sites	95	5.2
	Total (Minimum)[13]	**862**	**47.2**
Potential High Production	Non-Forested Vegetated: Alders and Old Fields[14]	1.3	0.1
	Suitable for High Production Forestry	331	18.2
	Total (Maximum)[15]	**333**	**18.2**

[1] Total Landbase: portion of the total landbase accounting for overlap of all previous categories.
[2] Policy protected 8% Old Forest layer polygons not included within Existing and Proposed Protected Areas.
[3] Moose meadows, brush, wetlands, beaver flowage, open bogs, treed bogs, barren.
[4] Cliffs, dunes, coastal rocks, rock barren, beach.
[5] Potential ownership layer errors, not recommended for License, right-of-ways, operability constraints, Aboriginal negotiated Crown land.
[6] Lynx habitat, moose habitat, coastal plains flora, boreal felt lichen and other special site habitat buffers.
[7] Wood turtle area, deer wintering area, marten patches, moose shelter patches.
[8] Regulation 20m buffers, main river Crown policy 100m buffers, open bog Crown policy 20m, buffers.
[9] Offshore/lake islands, low site productivity, steep slopes.
[10] Ecosections that represent <2% of ecodistrict or are heavily converted (>75%) to an unnatural state for anthropogenic use.
[11] Wet/Coastal/Highland/Floodplain/Karst Forest Groups.
[12] Acadian Ecosites 6 & 7, Spruce Hemlock (SH) 4/4a/12, SH & Intolerant Hardwood (IH) 6/6a Veg Types on Acadian Ecosites 10 & 11 with >10% black spruce/white pine/red oak.
[13] Matrix area will increase as further restrictions are applied at the landscape/operational planning level.
[14] Due to current state and past use, may be considered for conversion to plantation.
[15] High Production Forest area will decrease as further restrictions are applied at the landscape/operational planning level.

The remaining area potentially suitable for HPF using these considerations equals 333,000 ha (18.2%) of the Crown landbase. This is considered a maximum, because as further restrictions are set at the landscape and operational planning levels, areas that are unsuitable for HPF, for reasons not captured at a provincial scale, will be moved into the ecological matrix or conservation zones.

Of the 333,000 ha of potential HPF, 20% is within Central Region, 42% in Eastern Region, and 38% in Western Region. As a percentage of the Total Crown Land Area (1,824,000 hectares considered part of the triad), 3.7% of potential HPF is in Central Region, 7.7% in Eastern Region and 6.8% in Western Region.

Table 3. Regional summary of Crown land potentially suitable for High Production Forestry (HPF).

Region	Total Crown Land Area (ha)	Potential Suitable HPF		
		Area (ha)	Proportion of total HPF area by Region	Percent of total Crown land
Central	380,000	68,000	20%	3.7%
Eastern	699,000	140,000	42%	7.7%
Western	745,000	125,000	38%	6.8%
Total	**1,824,000**	**333,000**		**18.2 %**

Analysis Framework

The following provides a proposed method of analysis to determine area suitable for HPF.

The province was divided into a 10-metre (m) resolution raster for this analysis. 10 (m) was chosen as the finest resolution cell, as it adequately captured small linear features in the landbase (e.g. stream buffers, roads). A finer scale, 1m cell resolution, was explored, however the file size of a provincial raster at that resolution was too large to process efficiently. When converting vector data to this raster format the dominant attribute (by area) within a cell was assigned as the cell value at the 10m level.

These 10m cells were nested inside 100m cells, further nested in 1km cells (all with a unique grid identification) (Figure 1). These varying resolutions were developed for use at different stages in the selection analysis. At the strategic planning level, a 1km cell is sufficient to provide a high-level indication of areas to target and areas to avoid for high production forestry. At the finer tactical/landscape planning level, the 100m raster can support refinement of suitable sites. The 10m raster, at the operational planning/stand level can be used to avoid areas unsuitable for intensive management because of small scale features (such as stream buffers or steep slopes).

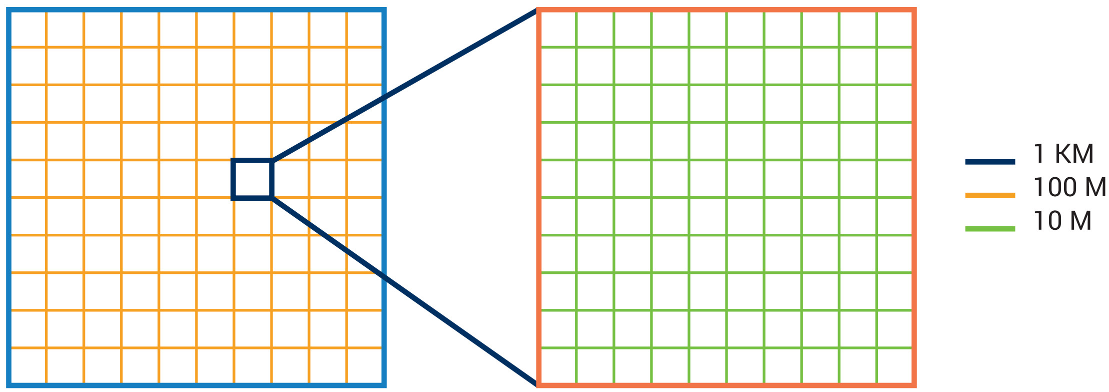

Figure 1. Illustration of nested raster framework used for High Production Forestry suitability analysis.

Area-weighted averaging of 10m cells to summarize the values within each 1km cell was used for this strategic-level assessment. This approach will result in many cells having a small fraction of their area on the suitable landbase for HPF.

Proposed Selection Criteria

The selection criteria are a major component of the HPF project plan. Coming up with potential criteria involved discussions within the HPF team as well as a literature review[9,10] . The most common criteria used in similar analysis were site productivity, distance to mill and location of existing plantations / old field sites. These were consistent with the HPF objective to produce high yields in areas located close to processing facilities.

The HPF team has identified proposed methods for ranking potential sites based on three sets of criteria: 1) areas must be highly productive 2) areas must be conducive to economic efficiency, and 3) areas must not have already been delineated for non-timber values. Areas where HPF is unlikely or not legally permitted to be established were excluded from the analysis area before suitability scoring.

Other selection criteria of note that were discussed are summarized in Table 4.

[9] Norfolk, C., & Erdle, T. (2005). Selecting intensive timber management zones as part of a forest land allocation strategy. The Forestry Chronicle. 81. 245-255.
[10] Messier, C., Tittler, R., Kneeshaw, D., Gélinas, N., Paquette, A., Berninger, K., Rheault, H., Meek, P., & Beaulieu, N. (2009). TRIAD zoning in Quebec: Experiences and results after 5 years. Forestry Chronicle. 85. 885-896.

Table 4. Summary of selection criteria considered but not used in this Phase of the High Production Forestry (HPF) analysis.

Criteria (considered but not used)	Reason
Proximity to Protected Area	There is currently a 100m buffer on Protected Areas in which clearcut harvesting is not permitted (partial harvesting is permitted). The impact HPF may have near a protected area depends on HPF area size and related management intensity. This can be addressed at the landscape/tactical planning level.
Proximity to Settlement	It is unclear whether it is a positive or negative indicator of suitability. Close proximity to settlements with high employment in the forestry sector may be desirable and thus be a positive factor, but in areas with low employment in the forestry sector it may be undesirable and thus a negative factor. With so much variation from community to community it is unfeasible to consider the diverse range of opinions at a provincial level.
Photo Interpreted Land Capability	This was initially considered for use in the productivity selection criterion but was replaced with the ecosite mapping layer. The ecosite mapping incorporates forest ecosystem classification (FEC) soil-type (ST), veg-type (VT) and forest group information which collectively improved productivity assessment.
Proportion of Crown Land	Used initially to score areas based on the concentration of Crown land in a cell, it was later removed because the analysis area is filtered to Crown land to begin with. Instead, minimum operable block size (approximately 25 ha) will be considered at the stand-level site selection.
Ecological Emphasis Class by Ecodistrict/Elements	It was discussed as possible selection criteria to reduce HPF ranking in ecodistricts/elements that currently have high levels of land converted to an unnatural state. It was decided this was important to consider yet would fit better under the HPF allocation process and/or landscape planning-level
Ecosystem-Based Management Approach	Ecosystem-Based Management (EBM) sets minimum area targets for specific forest maturity conditions by Ecoregion and Natural Disturbance Regime (NDR). These targets for Mature, Late Seral and Old/Multi-Age forest do not prohibit harvesting, but they can delay harvesting until the targets are met (often through letting stands grow to the required maturity class). Since these targets do not restrict harvesting entirely (if they apply to HPF areas) they will be included at the tactical planning level when timing of HPF establishment can be considered.
Other Wildlife Habitat Layers	There are many spatially identified wildlife habitat areas (Species at Risk, Nova Scotia Ecologically Sensitive Areas). If the management practice prohibits harvesting, it was removed from the suitable landbase. If restrictions within a habitat area are timing-related (for example, avoiding operations during nesting seasons), they were not used in this stage of the analysis. They will be included at the operational/stand selection level, where timing of HPF establishment can be considered.

Site Productivity/Ecosite

Ecosite was used as a productivity measure. Developed within the Nova Scotia Forest Ecosystem Classification[11] (FEC), Ecosite is a unit which represents ecosystems with varying conditions and influences but with similar moisture and nutrient regimes (Figure 2) and can be assigned based on knowledge of FEC vegetation and soil types. Ecosites with wet or dry moisture regimes, were excluded from this analysis, as excess or deficit moisture may hinder plant growth. Within the Acadian ecosites, those classified as poor/very poor were excluded, as they will not meet productivity needs of HPF. Very rich sites were excluded because they are typically associated with sensitive floodplains. All current tolerant hardwood stands/sites were excluded for biodiversity reasons (i.e. conversion from tolerant hardwood to a softwood plantation is not under consideration). Rich sites (ecosites AC13 and AC14) with current mixedwood or intolerant hardwood cover were also excluded because these stands will typically naturally succeed to tolerant hardwoods. However, rich sites with current softwood dominant cover were considered eligible. Mixedwood and intolerant hardwood on medium sites (ecosites AC10 and AC11) were also considered eligible because these sites normally support either softwood or mixedwood dominant cover at climax and are therefore less impacted by conversion to softwood plantations. Ecosites in the Maritime Boreal Coastal and Highlands forest groups were excluded due to high exposure and limited productivity, except for those already converted to plantations. The excluded ecosites are detailed in the 'Suitable Landbase' section above.

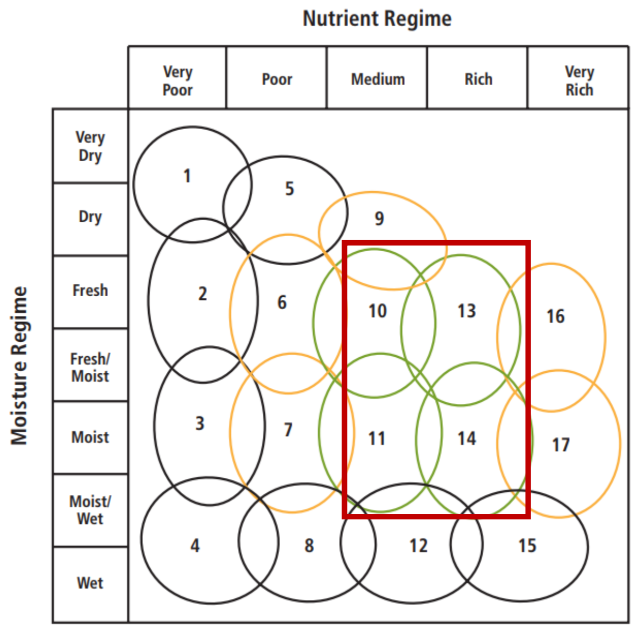

Figure 2. Edatopic grid showing relative moisture and nutrient regimes for Acadian group ecosites[5]. Ecosites suitable for high-production forestry are nutrient medium-rich, fresh-moist ecosites (outlined in the red box).

Acadian Ecosites 10, 11, 13 and 14 have been classified as suitable ecosites for intensive softwood plantation management within Phase 1 of this project. As there is significant overlap between expected ecosite productivity, all four ecosites were deemed equally suitable for HPF at the strategic planning level. Productivity estimates for red spruce on these ecosites range between 4.7 to 6.6 m^3/ha/year, while productivity estimates for white spruce on these ecosites range between 5.6 to 7.7 m^3/ha/year. Managed stands of improved seedling stock can be expected to produce an additional 2-4 m^3/ha/year[12]. This criteria was scored by calculating the hectares of suitable ecosite within each 1km cell.

[11] Neily, P., K., Keys, E. Quigley, S. Basquill, B. Stewart. (2013). Forest Ecosystem Classification for Nova Scotia. Report FOR 2013-1. Nova Scotia Department of Natural Resources. 452 pp.
[12] Projected Peak Mean Annual Increment, pp 25 in Nova Scotia Department of Lands and Forests. (1993). Forestry Field Handbook. 43 pp.

Past Management

Area existing in a plantation or old field state is viewed as a positive criterion for suitability. Old fields tend to have high site productivity and many softwood plantations may already exist on productive sites. Previously intensively managed areas (in the form of plantations or old fields) have a greater chance of being socially acceptable for high production forest management than areas currently in a naturally forested state. Old fields are often surrounded by existing agriculture, and highly productive forest plantations may be viewed as another crop (on a much longer rotation). Where plantations exist, the conversion from a natural forest to an intensively managed state has already occurred. This criterion does not address the issue of plantations on inappropriate sites – for which the appropriate management objective may be restoration (e.g., black spruce on an edaphic site). In these cases, sites may be better candidates for management in the Ecological Matrix zone. Identifying candidates for restoration is better addressed at the landscape or operational planning scales. This criteria was scored by calculating the hectares of past management within each 1km cell.

Distance to Sawmill

Following the example of Ward[13], "roadsheds" were delineated for the province. Where a watershed is a catchment basin for precipitation and snowmelt, a roadshed is a catchment basin for wood flow. A roadshed boundary determines the point where wood harvested is likely to flow based on harvest block operational conditions and distance to nearest woods road. The pour points in this case are intersections of woods roads and paved roads.

With a transport distance matrix linking roadsheds to the province's processing facilities, the average distance to the two closest sawmills for each roadshed was calculated. This criteria was scored by calculating an average delivery distance within the 1km cell.

Sawmill Selection. Sawmills acquiring greater than 10,000 m3 of softwood (from the 2018 Registry of Buyers Report14) were used as possible destinations:

- Elmsdale Lumber Co. Ltd.
- F.W. Taylor Lumber Ltd.
- Harry Freeman & Son Ltd.
- J.A. Turner & Sons Ltd.
- J.D. Irving (JDI) Ltd., Truro
- Ledwidge Lumber Co. Ltd.
- Lewis Mouldings & Wood Specialties Ltd.
- Scotsburn Lumber Ltd.
- Turner and Turner Lumber Ltd.
- Williams Brothers (2013) Ltd.

Although many small sawmills (acquiring less than 10,000 m^3 of softwood) exist and play a key role in supporting the provincial forest industry, the larger sawmills were chosen due to their high capacity. Small sawmills do not have the capacity to utilize large, localized increases in softwood timber supply. Although they will have access to timber produced on HPF sites, current reasoning suggests site selection should not be influenced by these smaller mills.

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[13] Ward, C. (2012). Tools to understand the spatial wood fiber supply-and-demand economics in New Brunswick's forest sector. Presented at the ESRI Forestry GIS Solutions Conference, Redlands, CA.
[14] Nova Scotia Department of Lands and Forestry (2019). Registry of Buyers of Primary Forest Products. 2018 Calendar Year. Report FOR 2019-001. 45 pp.

Pulp/Paper Mills. Inclusion of the province's pulp/paper mills in this indicator was initially explored. They were later removed to better align site ranking to the principles of high production forestry; to produce high-quality, high value softwood timber. Pulpwood is viewed as a secondary product of forest operations, compared to saw timber (sawlogs and studwood) which has greater value than roundwood pulpwood. In addition, by-products from the sawmilling process can be used by pulp/paper mills in their manufacturing process, so producing quality timber products for sawmills already has an indirect positive impact on pulp/paper mills. From this perspective, it was decided that distance to pulp/paper mills should not influence HPF locations.

Proposed Ranking

Ranking is the process of combining the selection criteria values across all three selection criteria to assign a relative ranking to all 1 km cells within the analysis.

Normalizing Indicators

The range and units of values within each selection criteria varies (for example suitable ecosite area can range from 0 to 100 ha, while distance to sawmill ranges from 5 to 357 km). Calculating a combined value of these two using absolute values, delivery distance will have a larger influence on the final score simply due to its scale. Furthermore, the units are not compatible (hectares vs kilometers). To address this bias and unit differences, values were normalized between 0 and 1 using min-max feature scaling (the minimum was assigned a value of 0, the maximum was assigned a value of 1).

$$\text{Normalized Value}(x') = \frac{x' - \text{Min}(x)}{\text{Max}(x) - \text{Min}(x)}$$

Where:

- *Normalized Value(x')* = normalized score (between 0 and 1)
- *x'* = indicator variable value
- *Min(x)* = minimum value of indicator variable
- *Max(x)* = maximum value of indicator variable

For indicators where the maximum score is desirable (e.g. plantation and old field area), the normalized ranking was reversed (so that the maximum value is transformed to a value of 0, and the minimum value is transformed to a value of 1. Values were multiplied by 100, (so that scores ranged from 0 to 100) instead of carrying decimal places with the scores.

Figure 3. Selection criteria distributions of actual values and normalized score values.

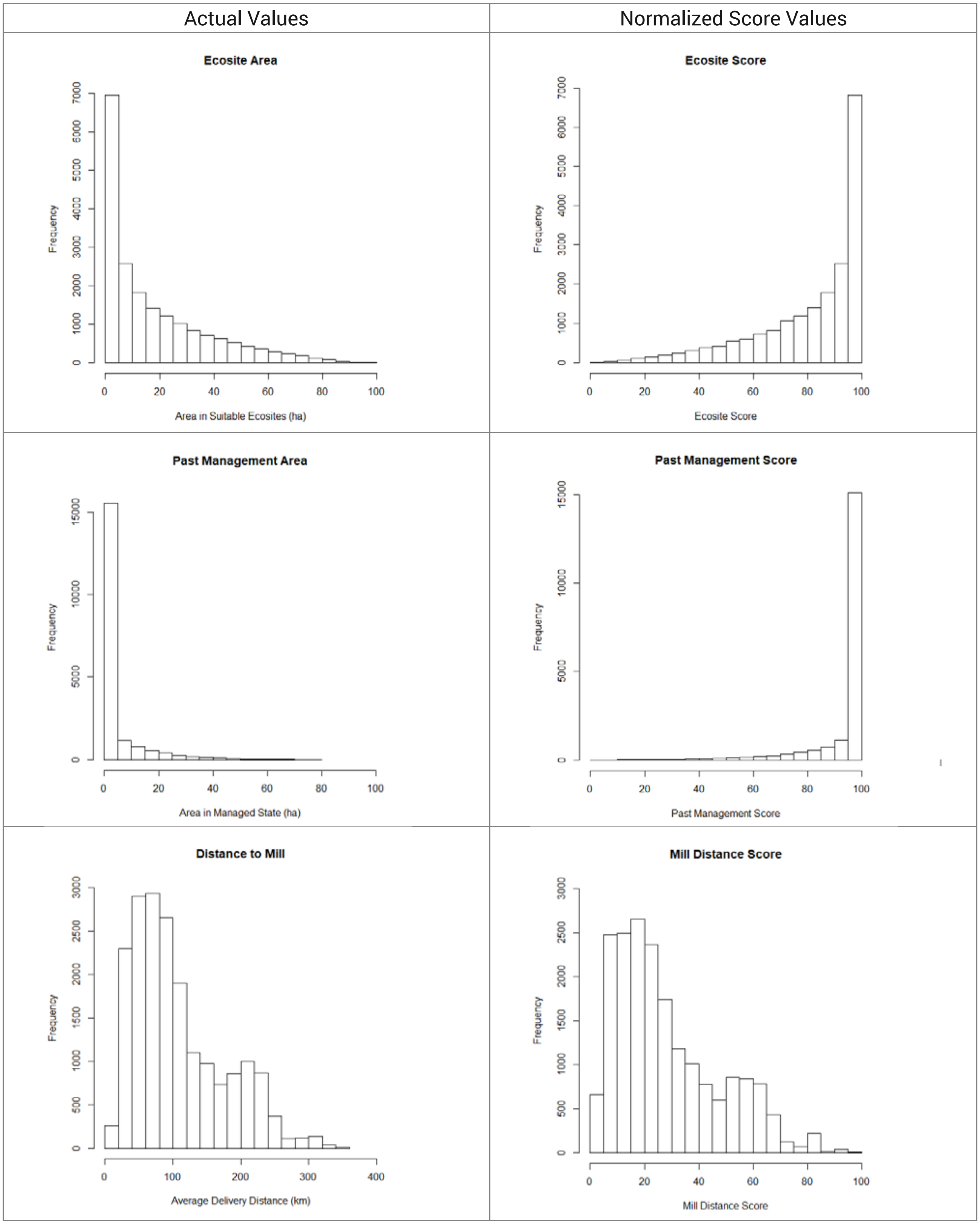


Figure 3. Selection criteria distributions of actual values and normalized score values.

Calculating Combined Rank Values

Cells were assigned rank values based on the Manhattan distance from the origin. The ideal cell (best possible candidate) with 3 criteria would have the coordinates (0,0,0) in a 3-dimensional space – resulting in a score of 0. The worst possible candidate would have the coordinates (100,100,100) in that same space – resulting in a score of 300. Cells were assigned a rank value using the sum of the normalized (0 to 100) scores of each selection criteria.

$$S_i = \sum_{j=1}^{J} W_{ij} P_{ij}$$

Where:

- S_i = overall suitability of cell i
- i = candidate cell
- j = indicator variable ranking
- W_i = relative weight of indicator variable
- P_{ij} = normalized rank of cell i of indicator j

Manhattan vs Euclidean Distance

For composite scoring, two common methods are Euclidean (straight-line distance from the origin to a point in n-dimensional space) and Manhattan (block distance, the vector sum of all indicators)[15]. Where Euclidean distance is the square root of the sum of the squares, higher emphasis is placed on outliers (the square term exaggerates the distance from the origin the further an indicator value is from the origin). Manhattan distance places equal emphasis on outliers and central values (relative differences across all values are maintained). Suitable ecosite area and past management area are heavily skewed towards low values. When weighing indicators for sensitivity analysis or final scoring, the formula for Euclidean distance creates noise in indicator weight on composite scores, because of the square and square root terms. With Manhattan distance, the weight applied increases (or decreases) the effect that indicator has on the total score at a 1:1 ratio. For these reasons, Manhattan distance was chosen to calculate composite scores.

Ranking Results using Proposed Ranking Methods

The results of the ranking process are intended to provide support for selecting high production areas within the 330,000 ha of suitable HPF landbase, as identified above. Across the proposed ranking criteria not all suitable HPF landbase is equal. The ranking results differentiates the suitability at a 1km cell level allowing the cells to be ranked for selecting and testing the proportion of area to be zoned as HPF. The analysis is proposing to examine the impacts of zoning HPF at 5%, 10%, 15% and 18%. These subsets will be selected based on cell ranking.

As the potential HPF area increases from 5% to 18%, average score worsens and actual indicator values (suitable ecosite area, past management area, and distance to mill) decrease (Table 5). Distance to mill remains relatively unchanged across the selection scenarios. Suitable ecosite area and past management area are heavily impacted as HPF area increases, reducing the average in a 1-km cell by 70% and 84%, respectively.

[15] Aggarwal C.C., Hinneburg A., Keim D.A. (2001) On the Surprising Behavior of Distance Metrics in High Dimensional Space. In: Van den Bussche J., Vianu V. Database Theory — International Conference on Database Theory 2001. Lecture Notes in Computer Science. Vol 1973. 420-434.

Table 5. Average score and indicator values of the top 5, 10, 15 and 18% of potential suitable High Production Forest (HPF) area.

HPF Area (%)	Total Area (ha)	Average (across 1km cells)			
		Score	Suitable Ecosite Area (ha)	Past Management Area (ha)	Distance to Mill (km)
5%	83,000	124	60	25	75
10%	166,000	149	49	16	76
15%	249,000	171	35	9	75
18%	333,000	205	18	4	108

When greater proportions of potential HPF area are selected, the areas that are included become less suitable based on indicator attributes. Concentration of suitable ecosite area within each cell decreases, decreasing potential operational block size. Past management area decreases, meaning it may be less socially acceptable to establish HPF in these areas. Distance to mill remains relatively unchanged, as the potential suitable HPF areas are concentrated around the mill locations used in this analysis.

Cell Ranking Example

Understanding what makes one cell rank higher than another is also important in understanding and applying any of the ranking results. Figure 4 and Figure 5 provide an illustration of what a high ranking cell would look like in comparison to a low ranking cell. Note that a ranking score of 0 is the best score, as it has the greatest similarity to the best of all selection criteria. Likewise, the further the score departs from 0 (the ideal condition) the lower the cell ranking. The 'High-Ranking' example has past management at 77 ha within the cell and a score of 0 indicating the best past management score, no other cell has more than 77 ha of past management. Similarly, criteria scores of 100 represent the worst case for any criteria. The overall cell score is simply the sum of the three criteria scores.

High Ranking Cell

Suitable Ecosite Area
78 ha (of a maximum 100ha)
Score = 20
Past Management Area
77 ha (of a maximum 100ha)
Score = 0
Distance to Sawmill
47 km
Score = 11

Combined Score = 31
Cell Rank = 2 out of 20338

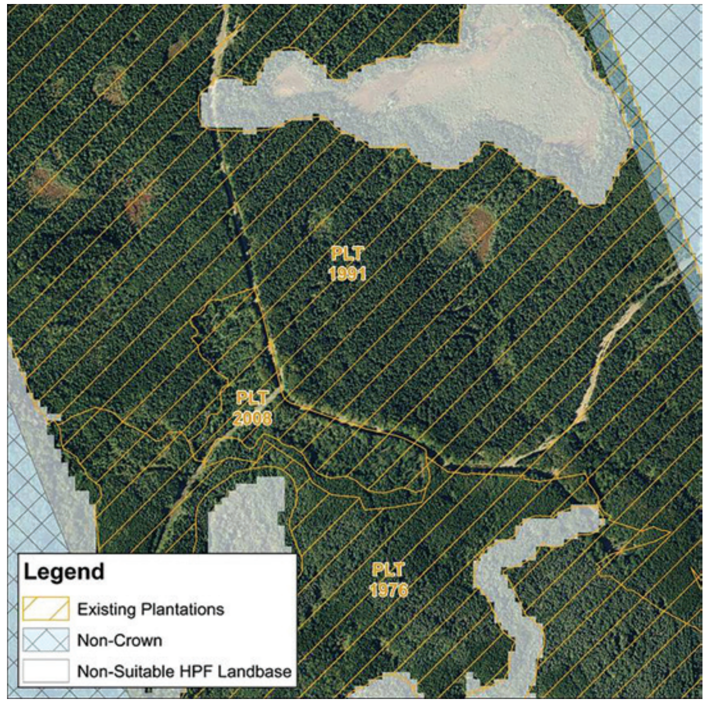


Figure 4. High-ranking cell based on suitable ecosite area, past management area, and distance to sawmill.

Low-Ranking Cell

Suitable Ecosite Area
3 ha (of a maximum 100ha)
Score = 100
Past Management Area
0 ha (of a maximum 100ha)
Score = 100
Distance to Sawmill
357 km
Score = 100

Combined Score = 300
Cell Rank = 20338 out of 20338

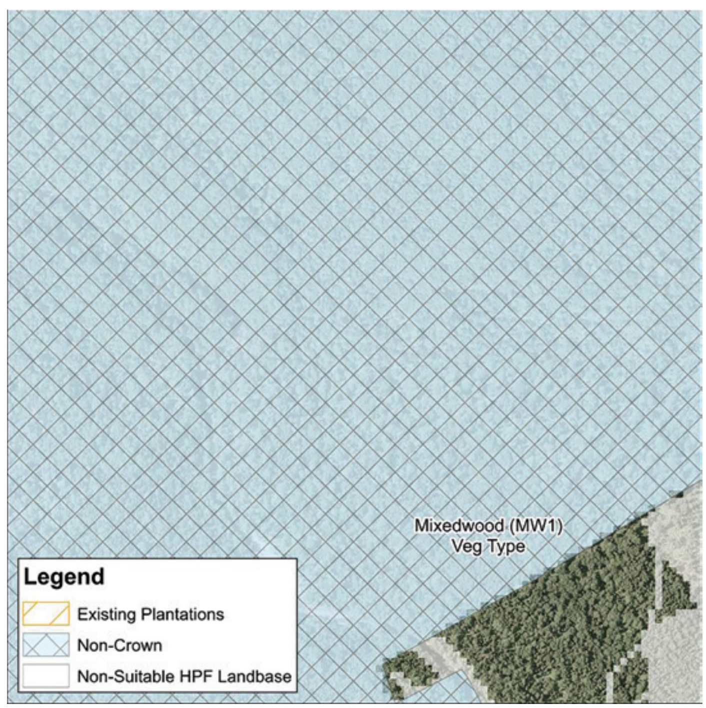


Figure 5. Low-ranking cell based on suitable ecosite area, past management area, and distance to sawmill.

Sensitivity Analysis

A sensitivity analysis was conducted using the 333,000 hectares of potential HPF to determine the robustness of selection criteria under a range of scenarios. Areas that consistently rank high for HPF under a range of scenarios (varying the relative importance, or weight, of criteria) are ideal candidates, as the uncertainty surrounding these areas is lowest. Areas that consistently rank as poorly suitable for HPF are, with a higher degree of certainty, poor candidates for HPF. Using the normalized selection criteria values, a range of weights were applied to the three criteria used to calculate individual 1km cell scores. This new weighted criteria value was used to re-calculate the rank of the cell.

Using the number of cells remaining in the top 30% as indicator provides an indication of the change in rank of the top 30%. If a low percentage of cells remain in the top 30%, then the relative rank values are sensitive to indicator weight changes. If a high percentage of cells remain in the top 30%, then the relative rank is insensitive to weighting of selection criteria values.

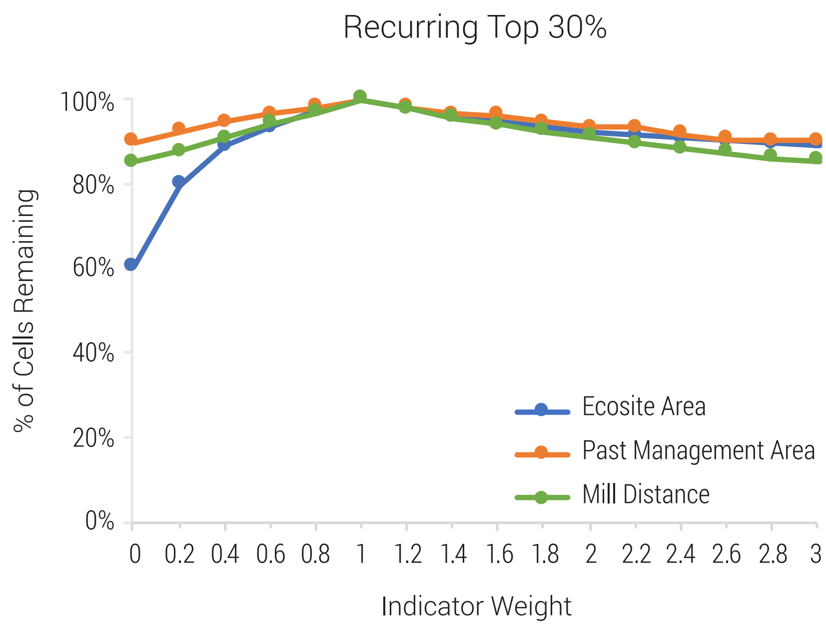


Figure 6. Percent of cells remaining in the top 30% across a range of selection criteria value weights. Criterion weight was changed for one selection criteria at a time, re-calculating cell rank and then selecting the top 30%. The number of cells in the base scenario (no weighting) was used to calculate the percent remaining.

As indicator weight is increased from 1 to 3, approximately 85% of cells initially in the top 30% remain in the top 30% (Figure 6). As indicator weight decreased from 1 to 0 for past management area and mill distance, 85-90% of the cells in the initial top 30% remain as such. Ecosite, when not included in the scoring, causes the top 30% of cells to change considerably, with only 60% remaining in the top 30%. This indicates that the analysis is sensitive to changes (mainly reductions) in the suitable ecosite area. Should additional ecosites be considered unsuitable (and removed from eligibility) further on in this analysis, the top 30% will experience significant change. Changes in other indicator values will cause lesser changes in the top 30%.

Next Steps

The Department of Lands and Forestry is seeking feedback on the proposed approach outlined in this discussion paper to inform this work and analysis to be completed as next steps to complete within Phase 1 of the HPF project. In particular, the Department is interested in hearing from stakeholders with responses to the following questions.

1. Do the practices described for HPF encompass a reasonable suite of treatments required to achieve HPF yields?
2. Related to the Triad Landbase grouping (Table 1 & Table 2), are there any areas that you think are incorrectly categorized? For example, including tolerant hardwood sites in the ecological matrix instead of eligible for HPF.
3. Do the Selection Criteria (Site Productivity, Past Management, and Distance to Mill) adequately represent sites suitable for HPF?
    - Do you have any concerns regarding how we applied the Selection Criteria?
    - What, if any, other Selection Criteria would you like to see included?
4. In Appendix A, are the yield targets reasonably achievable?
5. In Appendix A, do the suggested silviculture interventions and timing encompass the full suite of treatments required to achieve these yields?
6. What other concerns do you have moving forward into the implementation phase of HPF?

In addition to the analyses detailed in this discussion paper, the HPF team plans to complete a strategic, long-term wood supply analysis as part of Phase 1 of this project which will use the Crown Lands Forest Model (CLFM) to explore impacts of zoning varying amounts of total HPF area on Crown lands (e.g. 5%, 10%, 15%, 18%). Also included in this analysis will be the impact of ecosystem-based management (EBM) targets. This analysis, which will be a part of the Phase 1 final report, will allow the trade-offs of varying HPF area to be quantified when selecting the total area allocated to HPF in Phase 2. Input will be gathered from various stakeholders, the general public, L&F staff, and external experts through stakeholder engagement which will be used to finalize the Phase 1 report, detailing the methods and strategy used to identify potential HPF sites, along with potential wood supply and EBM target impacts of HPF. The final report will serve as the baseline for Phase 2 of the project, which involves site selection and classification of HPF on the landscape.

Appendix A. Silviculture Intervention Strategy by Species for the High Production Forestry Zone

The following silviculture intervention strategies have been designed for high production forestry (HPF) with expected results based on:

(1) Establishing intensively managed plantations on productive ecosites (primarily ecosites AC 10/11) as described in the Nova Scotia Forest Ecosystem Classification (FEC) system

(2) Yield projection from the Nova Scotia Growth and Yield (NSGNY) model – incorporating over 30yrs of permanent sample plot data directly from plantations,

(3) Relevant Forest Research Reports:

   a. Report #22 Revised normal yield tables for Nova Scotia softwoods,

   b. Report #24 Norway Spruce: Growth Potential for Nova Scotia

   c. Report #35 Yields of Selected Older Forest Plantations in Nova Scotia

   d. Report #43 Nova Scotia Softwood Growth and Yield Model Version 1.0 User Manual

   e. Report #77 For 2006-1.1 Growth Potential of "Old Field" Plantations in Nova Scotia

(4) Field verification of plantation yields with local conditions,

(5) Discussions with regional tree improvement program researchers

(6) Discussions with regional silviculture practitioners & forest managers

The proposed strategies were designed to align with HPF goals of producing quality, high value logs for the sawmill sector.

These assumptions will continue to be refined as better information becomes available. Any final strategies will additionally be put through an economic assessment to better link decision making within the HPF zone to final product value as opposed to solely quantity-based production (*i.e. maximizing value vs maximizing volume*).

As one of the key objectives of the High Production Forest zone is to grow an abundance of saw material products (i.e saw timber, or sawables), each of the species growth and yields have been modelled with this as the focus. Red spruce plantations have been modelled to achieve an average diameter of 12" (30cm), with a focus on maximizing sawlog volumes from a piece size which is efficient for sawmills to utilize. White spruce plantations have been modelled to achieve an average diameter of 10" (26cm), with a focus on maximizing both sawlog and studwood volumes from a piece size which is efficient for either stud mills or sawmills to utilize. Norway spruce has market limitations and cannot be utilized for sawlogs, therefore Norway spruce plantations have been modelled to achieve an average diameter of 8" (20cm), with a focus on maximizing studwood volumes from a piece size which is efficient for stud mills to utilize. This mix of piece of size distribution at time of final felling produces a high production forest zone with a more diverse age class structure than would be achieved growing all plantations to the same piece size and/or age, reducing risk while increasing product diversity and availability for a future market.

For each scenario, the NSGNY model runs were setup to illustrate expected plantation yields. Reported indicators for HPF plantation strategies run through the NSGNY model included:

- **Merchantable Height (Lorey's) –** Average height of merchantable trees (trees greater than 9.1cm diameter at breast height (DBH)) weighted by merchantable basal area
- **Merchantable DBH (QMD: Quadratic Mean Diameter) –** Average DBH of merchantable trees weighted by merchantable basal area
- **Merchantable Stem Count –** Count of merchantable trees per hectare
- **Merchantable Basal Area –** Sum of basal area of all merchantable trees per hectare
- **Merchantable Stand Volume –** Sum of volume of all merchantable trees per hectare

- **Merchantable Cumulative Volume –** Sum of volume of all merchantable trees per hectare that includes any volume removed through a commercial thinning operation
- **Merchantable Cumulative Log Volume –** Sum of sawlog and studwood (all logs having minimum 4" top) volume inclusive of log volume removed through commercial thinning
- **Merchantable Cumulative MAI –** Mean Annual Increment relative to cumulative merchantable volume and stump age

The following sections present details on each strategy along with a NSGNY model run for expected stand-level yield projections.

White Spruce

Key Assumptions

- Grow to produce sawlog timber
- Targeting a 10" (25cm) DBH tree size at Final Felling
- Establish on relatively higher fertility sites
- Incorporates tree improvement gains
- Expect 8-9 m3/ha/yr @ 85% stocking and site index of 24.6m@50yrs

Silviculture Interventions and Timing

Year 0 – Post-harvest mechanical site preparation

Year 1 – Plant seedlings (1736 stems/ha – 2.4m spacing)

Year 2 – Herbicide application*

Year 8 – Cleaning

Year 25 – Commercial Thinning (30% Basal Area Removal + 10% Trails)

Year 40 – Final Felling

*Very rich sites with lots of competition may require a second herbicide application (year 4-5), however it is expected with fast-growing improved trees, and the elimination of our richest ecosites from consideration, this will not be a common occurrence

Table A. **White Spruce:** NSGNY Model Results

Stand Stump Age (yrs)	Merch Height Lorey's (m)	Merch DBH QMD (cm)	Merch Stem Count (#/ha)	Merch Basal Area (m^2/ha)	Merch Stand Volume (m^3/ha)	Merch Culm. Volume (m^3/ha)	Merch Culm Log Volume (m^3/ha)	Merch Culm. MAI (m^3/ha/yr)
5	0.0	0.00	0	0.0	0	0	0	0.0
10	0.0	0.00	0	0.0	0	0	0	0.0
15	6.6	12.22	1198	14.1	31	31	8	2.0
20	9.0	15.37	1431	26.6	86	86	49	4.3
25	11.5	17.89	1464	36.8	156	156	130	6.2
25	11.8	19.34	729	21.4	78	156	130	6.2
30	13.8	22.03	731	27.9	144	222	195	7.4
35	16.0	24.17	732	33.6	202	280	259	8.0
40	18.0	25.92	732	38.6	264	342	313	8.5

Red Spruce

Key Assumptions

- Grow to produce large sawlog timber
- Targeting a 12" (30cm) DBH tree size at Final Felling
- Establish on medium-high fertility sites
- Incorporates tree improvement gains
- Expect 7-8 m3/ha/yr @ 85% stocking and site index of 22.5m@50yrs

Silviculture Interventions and Timing

Year 0 – Post-harvest mechanical site preparation

Year 1 – Plant seedlings (1736 stems/ha – 2.4m spacing)

Year 2 – Herbicide application**

Year 10 – Cleaning

Year 25 – Commercial Thinning (30% Basal Area Removal + 10% Trails)

Year 35 - Commercial Thinning (30% Basal Area Removal)

Year 45 – Final Felling

**Sites with high competition may require a second herbicide application

Table B. **Red Spruce:** NSGNY Model Results

Stand Stump Age (yrs)	**Merch** Height Lorey's (m)	Merch DBH QMD (cm)	Merch Stem Count (#/ha)	Merch Basal Area (m^2/ha)	Merch Stand **Volume** (m^3/ha)	Merch Culm. Volume (m^3/ha)	Merch Culm Log Volume (m^3/ha)	Merch Culm. MAI (m^3/ha/yr)
5	0.0	0.00	0	0.0	0	0	0	0.0
10	0.0	0.00	0	0.0	0	0	0	0.0
15	6.2	11.80	1108	12.1	29	29	5	1.9
20	8.1	14.73	1413	24.1	77	77	41	3.8
25	10.3	17.21	1459	33.9	136	136	122	5.4
25	10.6	18.61	727	19.8	68	136	122	5.4
30	12.4	21.26	730	25.9	123	192	178	6.4
35	14.4	23.40	731	31.4	171	239	214	6.8
35	14.9	25.25	439	22.0	103	239	214	6.8
40	16.3	27.72	439	26.5	160	296	276	7.4
45	18.0	29.82	439	30.7	202	338	319	7.5

Non-native Species (ex. Norway Spruce)

Key Assumptions

- Grow to produce studwood quality timber
- Targeting an 8" (20cm) DBH tree size at Final Felling***
- Establish on medium-high fertility sites
- No tree improvement gains
- Expect 9-10m3/ha/yr @ 85% stocking and site index of 25.7m@50yrs

Silviculture Interventions and Timing

Year 0 – Post-harvest mechanical site preparation

Year 1 – Plant seedlings (1736 stems/ha – 2.4m spacing)

Year 2 – Herbicide application

Year 7 – Cleaning

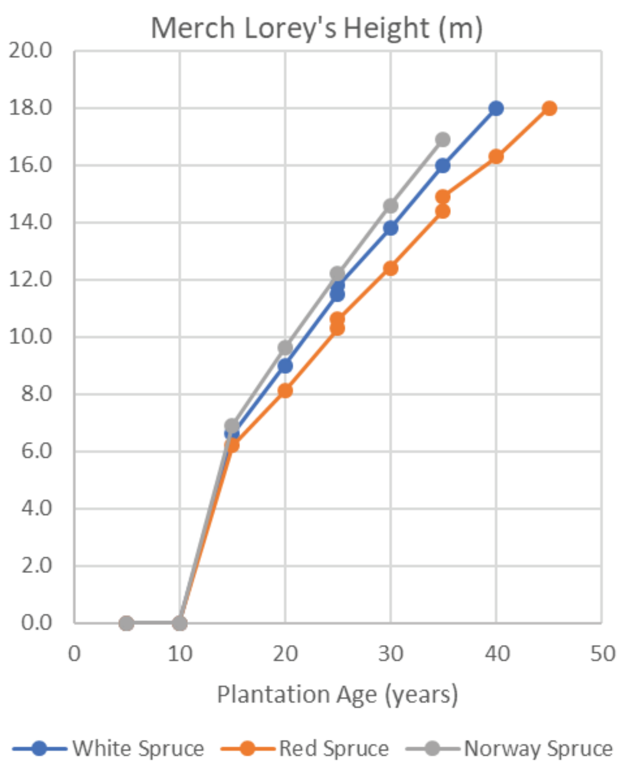
Year 30-35 - Final Felling

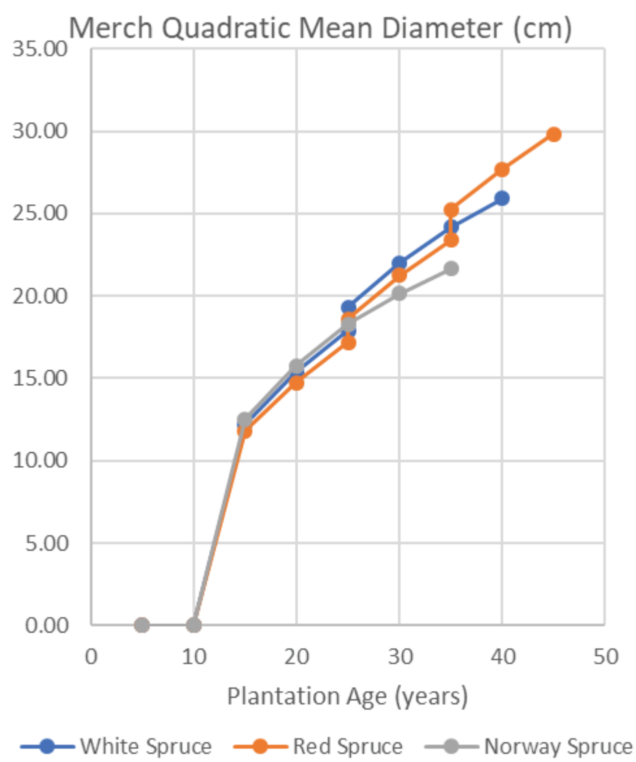
***Goal with Norway Spruce is to produce up to studwood size (20-22cm average DBH), but no larger as Norway cannot produce sawlogs in Nova Scotia due to market

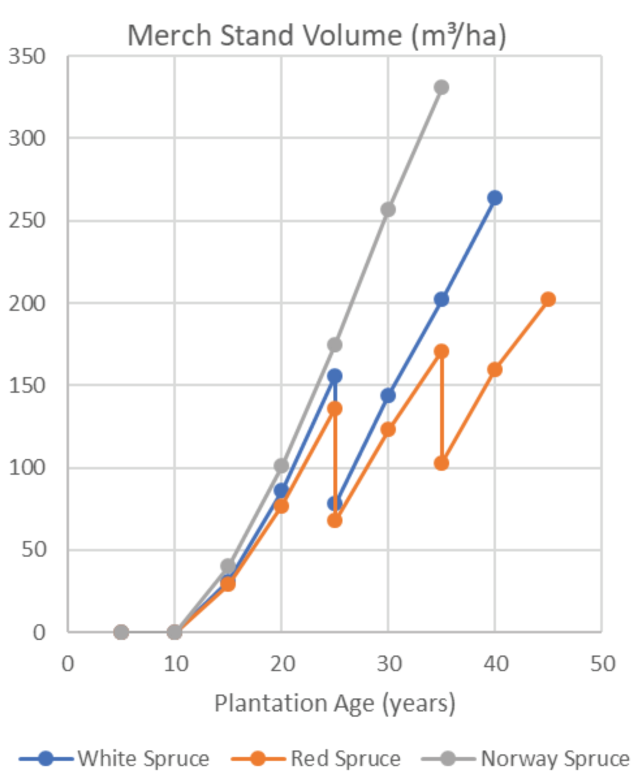
Table C. **Norway Spruce:** NSGNY Model Results

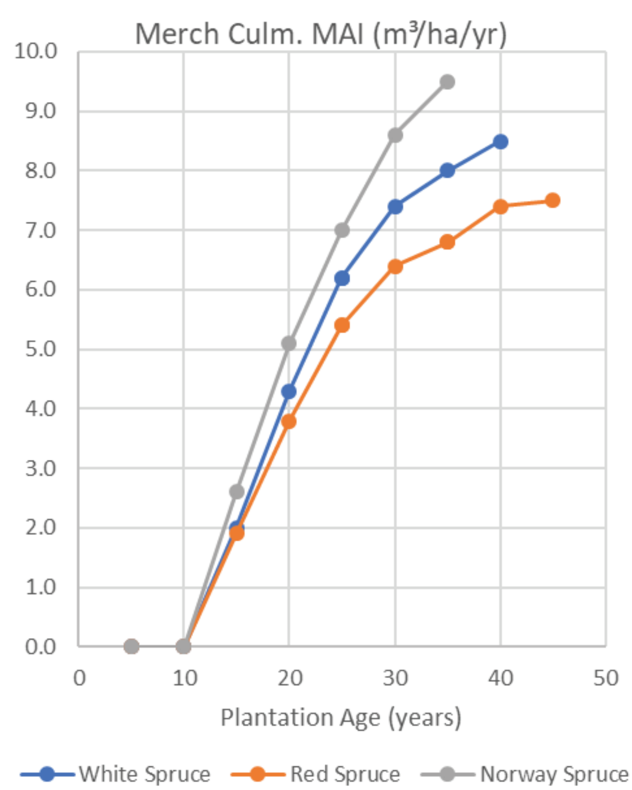
Stand Stump Age (yrs)	Merch Height Lorey's (m)	Merch DBH QMD (cm)	Merch Stem Count (#/ha)	Merch Basal Area (m^2/ha)	Merch Stand **Volume** (m^3/ha)	Merch Culm. Volume (m^3/ha)	Merch Culm Log Volume (m^3/ha)	Merch Culm. MAI (m^3/ha/yr)
5	0.0	0.00	0	0.0	0	0	0	0.0
10	0.0	0.00	0	0.0	0	0	0	0.0
15	6.9	12.52	1245	15.3	40	40	13	2.6
20	9.6	15.76	1440	28.1	101	101	80	5.1
25	12.2	18.28	1466	38.5	175	175	145	7.0
30	14.6	20.17	1472	47.0	257	257	232	8.6
35	16.9	21.64	1422	52.3	331	331	314	9.5

Nova Scotia Growth and Yield HPF Strategy Comparison









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