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Abstract: White spruce is primarily a boreal species with a geographic distribution that reaches the Arctic treeline from Alaska to Labrador. Throughout its extensive range, white spruce exhibits different growth and silvical characteristics. The Wabanaki-Acadian Forest Region is near the southern limits of its range and in Nova Scotia there appears to be unique dynamics not associated with the species elsewhere. White spruce is widely distributed throughout the province, occurring on most ecosites and in all but 11 of the 122 Vegetation Types (VTs) defined in the provincial Forest Ecosystem Classification (FEC) as a primary or minor species. The best growth occurs on rich, fresh-to-moist, medium textured soils, especially where soils have significant seepage inputs and/or organic matter enrichment. Many of the VTs contain white spruce that exceed 100 years of age with a maximum of 203 years, except for old field sites and plantations where tree longevity was typically under 60 years of age. White spruce is considered intermediate in shade tolerance and can regenerate under shaded conditions, though achieves its best growth under full sunlight. It is capable of effective release and good growth following 50-70 years of suppression, particularly on richer hardwood and mixedwood ecosites. White spruce seems to play several different ecological roles depending on ecosite conditions, which cause it to exhibit distinct silvical personalities reflective of the setting. These include acting as a primary succession pioneer of deforested sites (e.g., old fields), a mid-successional associate of low-to-medium fertility ecosites, and as a late successional climax associate on richer hardwood and mixedwood ecosites. White spruce is best known for its formation of old field or pasture spruce forests on abandoned agricultural lands, which are a unique and familiar part of Nova Scotia's rural landscape. However, while early growth is rapid the nutrient enrichment from past agriculture is quickly exhausted and the vigour of the spruce deteriorates, creating conditions for bark beetles and rapid stand mortality. Old field/pasture spruce forests regenerate very poorly following harvesting or natural mortality and do not return to a pure white spruce condition, instead beginning a slow transition toward their natural forest state prior to land clearing. Most modelling studies predict that white spruce will be among the most negatively impacted by climate change, though the species has phenotypic plasticity that may make it more adaptable to climate change than other colder-climate species. The establishment of white spruce plantations should likely be restricted to medium-to-high fertility ecosites with fertilization as an option. Moreover, evidence suggests that white spruce only acts as a long-lived species suitable for uneven-aged management on tolerant mixedwood and tolerant hardwood Acadian ecosites, which should be reflected in the provincial silviculture guidelines.

Keywords: White spruce; ecology; silvics; Nova Scotia; Wabanaki-Acadian Forest

1. Introduction

The ecology of white spruce (*Picea glauca* (Moench) *Voss*) in the forests of Nova Scotia has generally been associated with the reforestation of abandoned agricultural lands and the Atlantic coastal spruce-fir forest. In natural Acadian forests, white spruce is usually considered a minor, easily overlooked associate, primarily in shade tolerant hardwood forests with scattered individuals in red spruce (*P. rubens*)-balsam fir (*Abies balsamea*) forests. The Fernow (1912) inventory of the provincial forest described white spruce as not being the principal softwood species. He also stated that it occurs in natural forests only in small numbers, amounting to less than 10%of these stands. Despite this, he states that it grows in more abundance in pastures, openings, and along coastal areas.

More recently, the extensive sampling required to prepare the Forest Ecosystem Classification (FEC) for Nova Scotia (Neily et al., 2023) revealed the presence of white spruce in more forest ecosystems than previously understood. The recent adoption of an ecological forest management approach (Lahey, 2018) on Crown lands and its encouragement on private lands has increased the need to better understand the silvics and ecological role of white spruce in Nova Scotia and the Wabanaki-Acadian Forest Region.

White spruce in Nova Scotia generally occurs in abundance when regenerating in abandoned agricultural lands. It is also often used in softwood plantations. Referred to as pasture spruce, or cat spruce due to its distinctive odor, white spruce has been a significant contributor to the provincial wood supply. A little under two million hectares of Nova Scotia was agricultural land in the early twentieth century. The abandonment of hundreds of thousands of hectares of farmland in the early twentieth century resulted in the reforestation to nearly pure forests of white spruce. These forests were often well stocked and produced large volumes of pulpwood and sawlogs. White spruce is also most notable along the Atlantic coastline and is a significant component of the climax spruce-fir forest found there. The species is very salt tolerant and even on the most exposed sites, for example, headlands and barrier beaches, white spruce is found, albeit in a stunted form.

White spruce can be found across Canada, extending northerly to the limits of the tree line. It is considered a dominant boreal forest species and achieves its greatest dominance in northern Canadian forests. Throughout this extensive range, white spruce exhibits different growth and silvical characteristics. Even in Nova Scotia, there appears to be unique dynamics not associated with the species elsewhere.

With the critical importance of fully understanding the silvics of dominant species and the uncertainty regarding the future forest due to climate change, the need for research on this dynamic species is high. The role of white spruce in the forests of Nova Scotia, whether it be in the dominant Acadian (AC) Forest or the much smaller Maritime Boreal (MB) Forest (Fig. 1), has not been fully assessed. Arguably, white spruce is the most diverse, dynamic, and often misunderstood tree of the Wabanaki-Acadian Forest Region.

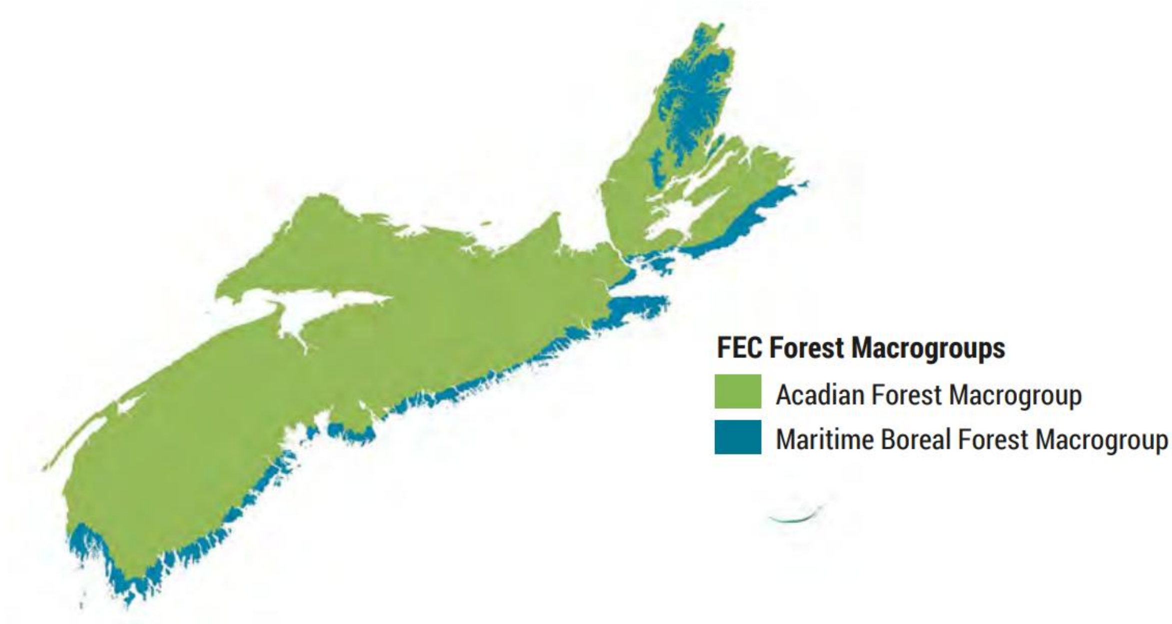

Fig. 1. The spatial extent of the climatic defined Acadian and Maritime Boreal Forest macrogroups, taken from Keys et al. (2023, p. 74).

This report on white spruce is a synthesis of existing research and data in the Acadian Forest region, with a primary emphasis on Nova Scotia. It includes new field observations and analysis of existing data. The study was conducted through the lens, and with the data from, the provincial FEC (Neily et al., 2023; Keys et al., 2023), the Ecological Landscape Classification (ELC; Neily et al., 2017), forest inventory program, and silvicultural research program of NSDNR.. The intent of this report is to use on-going NSDNR research and professional observation to inform future research and management that will better recognize the ecological and silvicultural role of white spruce in the Acadian Forest.

2. Distribution

White spruce spans the northern half of North America reaching the coastline of the Atlantic Ocean, extending as far north as the tree line, and occurring on the eastern side of British Columbia's Coast Mountains. Its southerly range covers the northern portions of the Great Lakes states and the border states of New England, including most of Maine.

Fernow (1912) stated that "white spruce is not, as is so often believed and claimed, the principal species" in his report on forest conditions in Nova Scotia. He describes white spruce in natural, unmanaged forests as occurring only in small numbers, hardly exceeding one per cent. "But on pastures and openings, it rapidly takes possession of the ground, and in those conditions grows exceedingly rapidly. It occupies especially the coastal regions, and probably is most abundant in Digby and Yarmouth counties and on the Canso side of Guysborough County" (Fernow, 1912, p. 11).

In the most recent measurements of almost 3000 permanent sample plots (PSPs), white spruce was found to comprise just 4.9% of forest biomass (Steenberg & O'Keefe, 2024), while the photo-interpreted inventory suggests that white spruce covers approximately 7% of the forested land in Nova Scotia (MacLean et al., 2022). Summarizing data from 1600 PSPs, Bailey and Wellings (1981) reported that white spruce dominated stands greater than 80% in composition made up 9% of Nova Scotia's forested area around 1980. White spruce also commonly grows in mixes with other species, typically amounting to less than 50% of the stand. It can be found most frequently in tolerant hardwood, mixedwood and spruce-hemlock mixed-species stands (Neily et al., 2023). High proportions of white spruce are only common in old field, coastal, and highland forests.

Modern inventory methodology and extensive provincial sampling for the FEC and the PSP inventory now show that white spruce occurs almost everywhere in Nova Scotia, although its abundance is stronger on the eastern mainland and along the Atlantic coastline and throughout Cape Breton Island (i.e., the Maritime Boreal macrogroup of the FEC). Aerial photo interpretation of forest cover illustrates the occurrence of white spruce and its abundance in eastern Nova Scotia (Fig. 2). The granite-derived soils of the Western Ecoregion and the quartzite dominated soils of the Eastern Ecoregion excluding landforms such as drumlins and floodplains have the lowest densities of forested area with a white spruce component, suggesting a limiting factor (e.g., soil nutrients and pH) to the establishment of white spruce.

Notably, these two ecoregions are home to some of the province's best and most extensive Acadian forests of red spruce. However, red spruce has reduced frequency on the eastern mainland and near absence on Cape Breton Island (Fig. 3). Considering the strong boreal affinity of white spruce and the absence of red spruce in the boreal forest it might be considered that there is a climatic transitioning happening in eastern Nova Scotia and on Cape Breton that enhances the occurrence of white spruce and limits red spruce.

White spruce is a species that quickly reforests abandoned agricultural lands with well-to-moderately-well drained soils. Larch (tamarack; *Larix laricina*) is another species that also reforests old field sites preferring those of imperfectly drained soils. However, in western Nova Scotia white pine (*Pinus strobus*) rather than white spruce tends to reforest abandoned agricultural sites, especially on drumlin landforms. This is very similar to what happens in New England where white pine is the dominant species to reforest abandoned agricultural lands. It should be noted that other species may also preform this role but typically it is limited and a function of enhanced soil fertility (e.g., white ash; *Fraxinus americana*) or seed source availability (e.g., red oak; *Quercus rubra*).

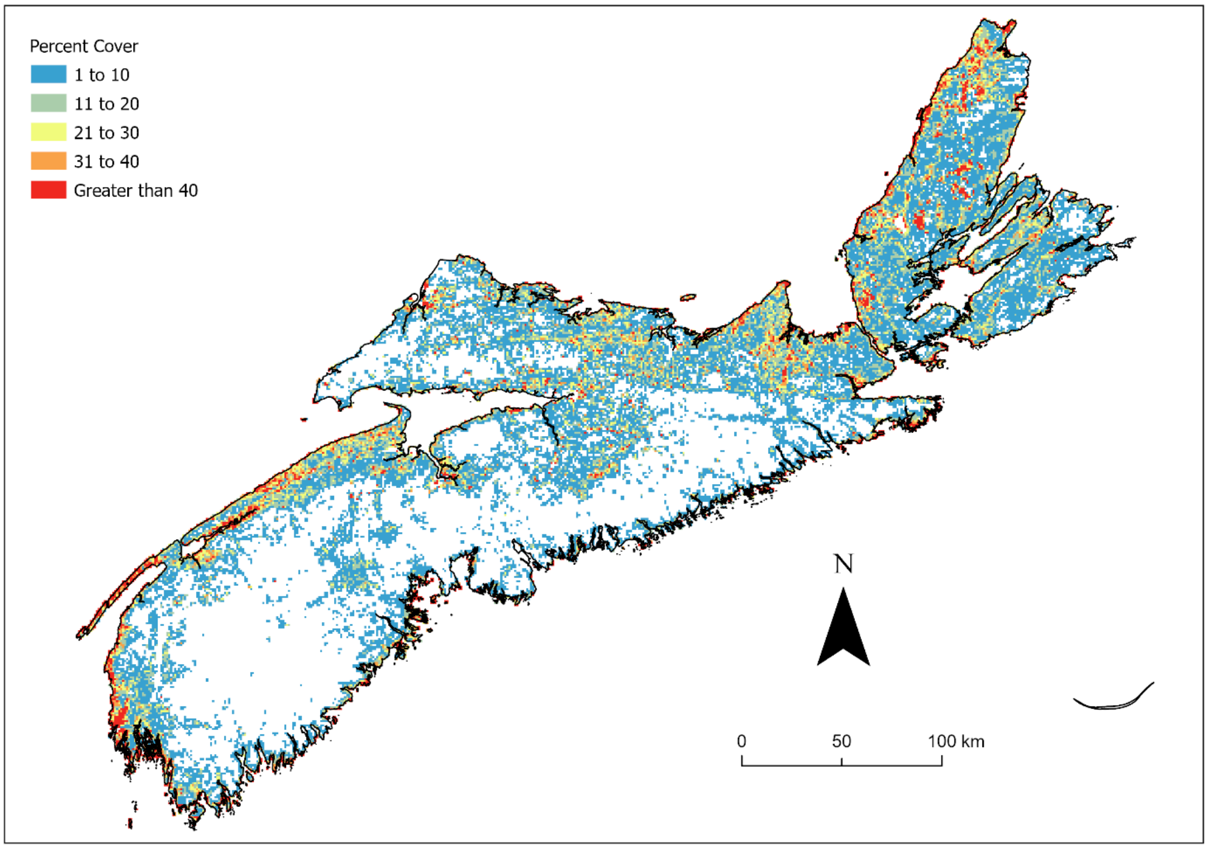

Fig. 2. White spruce cover derived from the photo-interpreted forest inventory, which includes natural stands as well as plantations and old field sites.

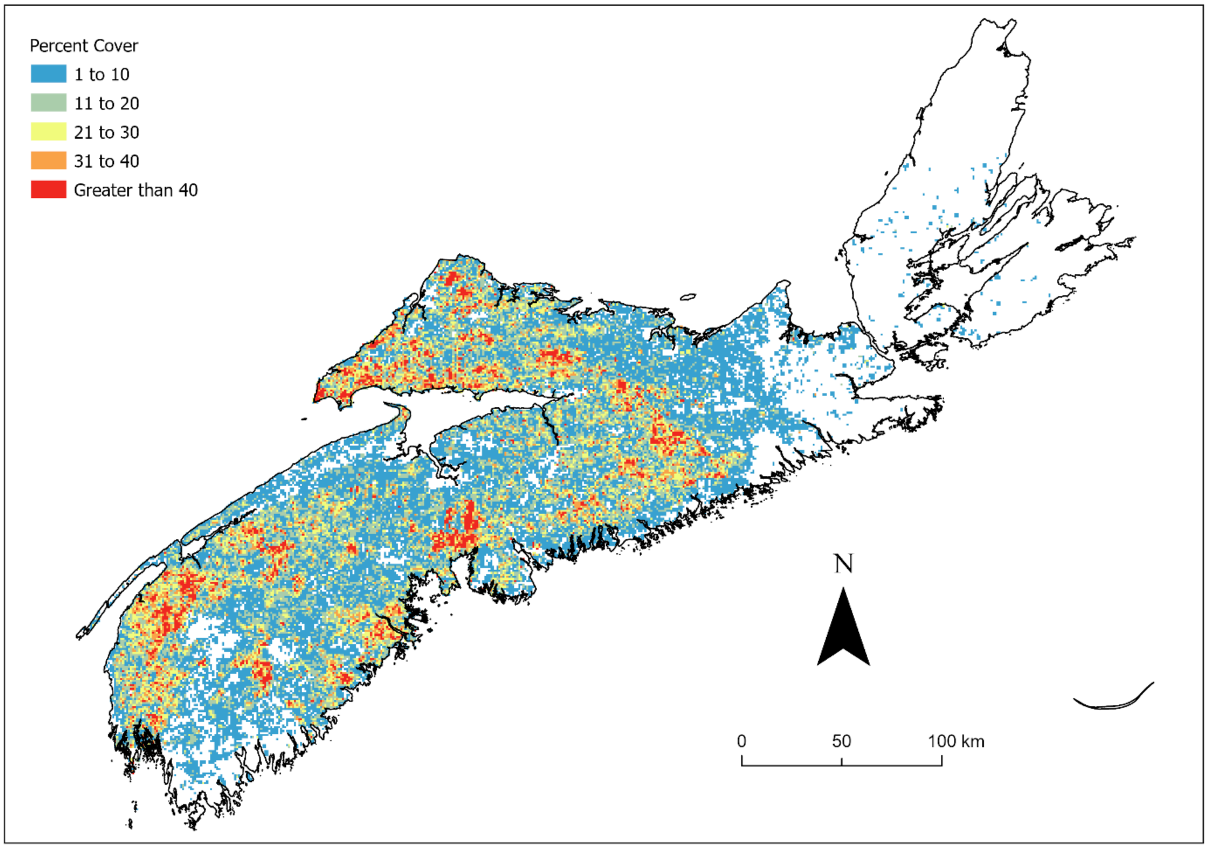

Fig. 3. Red spruce cover derived from the photo-interpreted forest inventory, which includes natural stands as well as plantations.

3. Climate and Climate Change

Climatic data for Nova Scotia is problematic due to an historical tendency for Environment and Climate Change (ECCC) weather stations to be located in communities, along major highways, and near the coast. However, inland weather stations have been recently established by NSDNR to improve the collection of weather data representative of the interior and assist in wildfire protection. Overall, white spruce abundance in Nova Scotia seems to be highest in those areas receiving at least 1,400 mm of annual precipitation (Table 1). A relationship with mean summer or winter temperature is weak. Figures 4 and 5 show the relative abundance of white spruce and red spruce for comparison across mean annual temperature and precipitation gradients. White spruce shows clustering in abundance around the warmest temperatures as well as the coldest, wettest temperatures, while red spruce is more broadly distributed and not as abundant in extremes of temperature or precipitation.

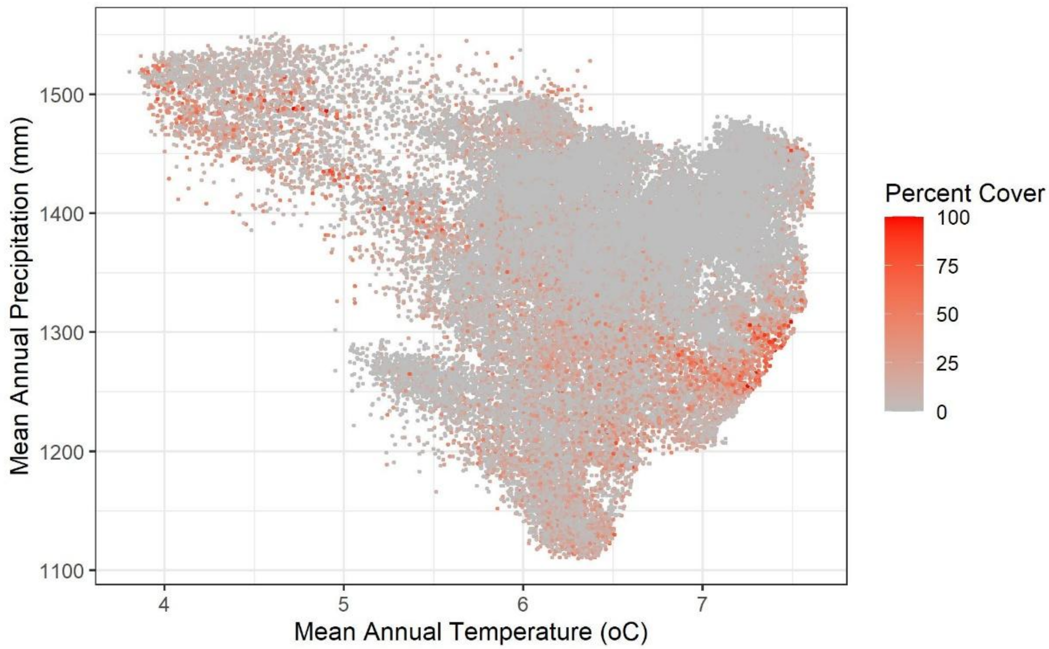

Fig. 4. White spruce distribution along temperature and precipitation gradients. Each point in the plot represents a 1000-m grid cell in a provincial raster dataset.

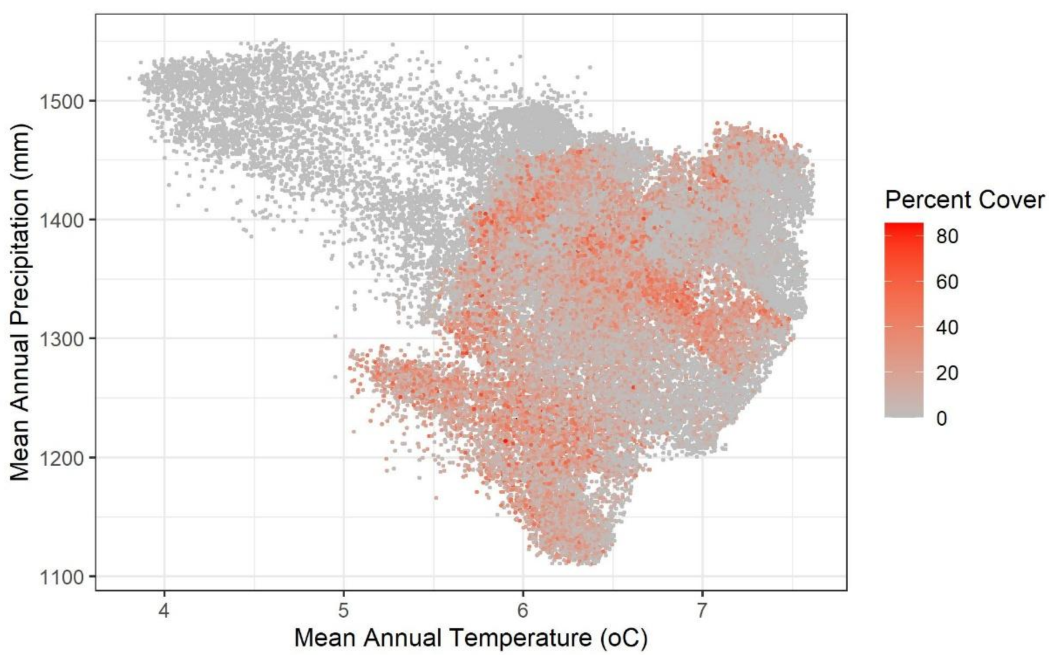

Fig. 5. Red spruce distribution along temperature and precipitation gradients. Each point in the plot represents a 1000-m grid cell in a provincial raster dataset.

Table 1. Climatic values (Webb & Marshall, 1999) and the abundance of white spruce for the ecoregions/ecodistricts of Nova Scotia (Neily et al., 2017).

Ecoregion	Mean Temperature (ºC) Summer	Winter	Annual Precipitation (mm)	White Spruce Abundance[3]
100 Northern Plateau	16.5	-4.0	>1600	Very high
200 Cape Breton Highlands	16.5	-4.0	1400-1600	High
300 Nova Scotia Uplands (E)[1]	16.5	-4.5	1500	High
300 Nova Scotia Uplands (W)[1]	16.5	-5.0	1200-1400	Low
400 Eastern	16.5	-5.0	1400-1500	Low
500 Northumberland / Bras d'Or (E)[2]	16.5	-4.5	1400-1500	High
500 Northumberland / Bras d'Or (W)[2]	15.5	-5.5	1000-1300	Medium
600 Valley and Central Lowlands	17.0	-4.5	1100-1300	Medium
700 Western	16.5	-3.5	1300-1500	Low
700 Western (Ecodistricts 730,740)	16.5	-3.5	1300-1500	Medium
800 Atlantic Coastal	15.5	-3.0	1400-1500	Very High
900 Fundy Shore (Ecodistrict 910)	16.5	-5.5	1250	Low
900 Fundy Shore (Ecodistrict 920)	16.5	-3.5	1200	Low[4]

[1] E: more eastern Ecodistricts 320, 360; W: more western Ecodistricts 330, 340, 350, 370, 380
[2] E: more eastern Ecodistricts 310, 510, 520; W: more western ecodistricts 530, 540, 550, 560
[3] Old field forests and plantations of white spruce excluded
[4] Excludes areas exposed to strong coastal influence (e.g., Digby Neck, Long and Brier Islands)

White spruce is primarily a boreal species with a geographic range that reaches the Arctic treeline from Alaska to Labrador. Nova Scotia and the Acadian Forest Region are near the southern limits of its range and indeed the defining characteristic of the region is the mix of colder-climate boreal species and warmer-climate temperate species. This attribute of the Acadian Forest means that some tree species will be better suited to the warming climate while others will not. At a relatively coarse scale, most modelling studies predict that white spruce will be among the most impacted by climate change, along with balsam fir, black spruce, and white birch (Steenberg et al., 2013; Taylor et al., 2017; Albert et al., 2023).

Several empirical studies suggest that white spruce may experience notable growth benefits from climate warming where water availability is not limiting, especially in colder climates (D'Orangeville et al., 2018; Wang et al., 2023). However, there is an optimum in these growth benefits and beyond certain temperature maximums sharp declines in productivity are predicted. The 4º C of warming predicted for Nova Scotia (Nova Scotia Department of Environment and Climate Change, 2022) suggest negative outcomes are more likely, which will be a critical area of adaptation for forest managers and landowners. Moreover, while higher mean annual precipitation rates are generally forecasted for Nova Scotia, it is also anticipated that drought events during the growing season will also increase in frequency and severity (Nova Scotia Department of Environment and Climate Change, 2022), further reducing the likelihood of any potential productivity gains.

White spruce is known to have higher nutrient demands than other softwoods, especially in certain settings (e.g., plantations, old fields), and experiences decline and mortality rates above what would be expected from competition alone (Steenberg et al., 2023). The interactions of these dynamics – and in general the tendency for white spruce to be a longer-lived, tolerant species in some ecosites/forest groups but not others – adds further uncertainty to its vulnerability to climate change. Further uncertainty exists also in the forecasted climate data and any future mitigation efforts, along with the uncertainty of species and ecosystem response to climate change. However, white spruce is generally described as having phenotypic plasticity (Burns & Honkala, 1990), which may make it more adaptable to climate change than other colder-climate species (Lu et al., 2014). On-going research on white spruce under climate change will be important.

4. Soils and Topography

White spruce in Nova Scotia can be found on soils derived from a variety of parent materials including glacial till, glaciofluvial, alluvium, glacio-marine, and organic materials. Regionally, these soils overlie greatly differing substrata, including plutonic (i.e., granite, diorite, gabbro) and metamorphic (i.e., gneiss, schist) rocks on the Cape Breton Highlands ecoregion, metamorphic, intrusive, and volcanic rocks of the Pre-Cambrian to Paleozoic eras on the Uplands ecoregion, folded Paleozoic slates and quartzites intruded with granites in the Eastern and Western ecoregions, Carboniferous sedimentary rocks in the Northumberland Bras d'Or ecoregion, Triassic sandstones and Carboniferous shale, sandstones, gypsum, and limestone in the Valley and Central Lowlands ecoregion, and basaltic flows underlying portions of the Fundy Shore ecoregion.

Despite this range in parent materials, white spruce is mainly associated with medium-to-rich, fresh-to-moist soils derived from glacial till deposits (i.e., ecosites AC10/11, AC13/14, and MB 5/6; Neily et al., 2023). Occurrence on these ecosites represent 65% (AC) and 72% (MB) of all plot occurrences noted during FEC sampling. The best growth occurs on medium textured soils (ST2L, ST3L, ST8, and ST9), while soils enriched by seepage can create conditions for exceptional growth. Abandoned agricultural lands where organic matter enrichment has occurred through pasturing or tillage (i.e., Ap horizons) often regenerate in pure, old field or pasture white spruce. However, while early growth is rapid on these sites, vigour is generally short-lived compared to undisturbed sites, creating conditions favourable to bark beetle attack and subsequent stand-level mortality.

The elevational range of white spruce goes from sea level to a maximum 535 m in the Cape Breton Highlands. At higher elevations, exposure restricts potential tree height and the species can become stunted, at times approaching a krummholz-like appearance. This condition also exists on exposed headlands along the Atlantic coast. In contrast, white spruce is often the tallest tree found in Upland (i.e., Ecoregion 300) tolerant hardwood and mixedwood forests, extending several metres above associated hardwoods.

5. Associated Trees and Shrubs

White spruce has a wide distribution throughout Nova Scotia, occurring on most ecosites within the Acadian and Maritime Boreal macrogroups (Neily et al., 2023). It occurs on both zonal and edaphic ecosites and of the 122 VTs, it occurs in 111 either as a primary or minor species in the overstory or regeneration layers. Predominant examples in the Acadian VTs include MW5 and MW6 in the Mixedwood Forest Group and SH6 and SH7 in the Spruce Hemlock Forest Group as primary species, with important minor species associations in SP10 in the Spruce-Pine Forest Group and TH2 in the Tolerant Hardwood Forest Group. See the FEC guides (Neily et al., 2023; Keys et al., 2023) for a complete breakdown of species associations across all VTs.

In addition to the named species listed in the VTs above, white spruce associates with beech (*Fagus americana*), hemlock (*Tsuga canadensis*), white pine, trembling aspen (*Populus tremuloides*), large-tooth aspen (*P. grandidentata*), red spruce, and tamarack. White spruce is a minor associate in all nine zonal VTs of the Tolerant Hardwood Forest Group. When it occurs there, it is typically less than 5% of the stand composition and is associated with sugar maple (*Acer saccharum*), beech, yellow birch (*Betula alleghaniensis*), red maple (*A. rubrum*), white ash, and ironwood (*Ostrya virginiana*) and should be considered a late-successional species (Neily et al., 2023).

White spruce is an early successional species on abandoned agricultural lands forming pure stands on the zonal soils. However, white spruce is an associate with tamarack on moist-to-wet old fields and, if soils are richer, it will be found with white ash. Other associates on old field sites include black cherry (*Prunus serotina*), red oak, trembling aspen, balsam fir, grey birch (*B. populifolia*), white pine, and eastern white cedar (*Thuja occidentalis*). Typical shrubs with an old field forest of white spruce include speckled alder (*Alnus incana*) and wild raisin (*Viburnum nudum*).

White spruce can be an associate in all nine of the VTs that make up the Floodplain Forest Group. It can be a primary early successional species after floodplain formation or after some level of human disturbance (e.g., agriculture) and associates with balsam poplar (*P. balsamifera*), black cherry, white ash, and red maple, as well as shrubs like speckled alder and chokecherry (*P. virginiana*). In later successional floodplain forests, it can be a minor associate with sugar maple, red oak, red maple, white ash, and ironwood. On karst topography, white spruce may be found as a minor associate in all four of the VTs in the Karst Forest Group and where there is extensive exposure to gypsum, it may be a primary species with round-leaved dogwood (*Cornus rugosa*) and mountain maple (*A. spicatum*).

White spruce can be a component in any VT associated with wet, medium-to-rich ecosites. Other associates in addition to those named on wet ecosites include red spruce, black spruce (*P. mariana*), hemlock, white pine, tamarack, red maple, white birch (*B. payrifera*), white ash, large-tooth aspen, trembling aspen, sugar maple, and black ash (*F. nigra*). In the wet forests of the Acadian Macrogroup, white spruce is a primary species in WC9 in the Wet Coniferous Forest Group and WM4 in the Wet Mixedwood Forest Group, along with WB2 in the Wet Boreal Forest Group of the Maritime Boreal Macrogroup.

White spruce is a prominent species in the Maritime Boreal Forest Macrogroup. It is a primary species in CB2 in the Coastal Boreal Forest Group and HL2 in the Highland Forest Group, as well as being an important minor associate in CB2, CB4, CB5/6, HL1, HL3, and HL4. In addition to the named species in the VTs, white spruce associates with black spruce, tamarack, red maple, and mountain ash (*Sorbus* spp.).

In coastal conditions, shrubs associated with white spruce include bayberry (*Myrica pensylvanica*), downy alder (*A. viridus*), mountain holly (*Ilex mucronata*), and several ericaceous shrub species. Under highland conditions, shrubs include mountain holly, downy alder, fly-honeysuckle (*Lonicera canadensis*), and mountain maple.

6. Silvics

One core objective of this study is to refine silvics information for white spruce in Nova Scotia. Burns and Honkola (1990), Farrar (1995), and Harrison (n.d.) were used as the foundational documents on white spruce silvics. Where refinement could be made based on Nova Scotia data and information, it was included here. Lastly, gaps in information were discovered in carrying out this study. Suggestions for research to fill these gaps are made in Section 10.

6.1. Seed Production and Dissemination

White spruce cones mature and open in the fall, mostly in late August through September. Cone collection in Nova Scotia’s seed orchards often begins in mid August. After the cones mature and open, the seed is disseminated by wind and can travel 200 m from the tree (Harrison, n.d.). It does not remain viable for longer than a year. The seed can germinate shortly after it falls if it occurs in early fall but mostly germinates starting in the following spring until the early summer after a period of stratification. It can regenerate under mature cover but is considered less tolerant of shade than red or black spruce. In naturally regenerated stands, white spruce starts to seed at 30 years of age and reaches its full seeding potential at 60 years (Harrison, n.d.).

In plantations, white spruce is known to produce cones at an early age, typically less than 10 years (Stiell, 1976). White spruce can remain in the understory for long periods of time with slow growth and is capable of quick growth once released. One year old seedlings can be from 1-2 cm tall and usually not more than 50 cm at five years of age under natural conditions. In naturally regenerated, open-closed conditions it will take between 10-20 years to reach breast height (1.3 m tall). In white spruce plantations when competition is controlled, seedlings can reach breast height in only 2 to 7 years (Steenberg et al., 2023). In the forest nursery, white spruce are the most sensitive species to changes in light or nutrients and their tendency to rapidly cease growth and set bud in response to minor changes in these growing conditions presents a challenge to growers (S. Gillis, personal communication, 2024).

6.2. Microsite Requirements

White spruce regenerates best on mineral soil microsites, perhaps accounting for its prolific occurrence in Nova Scotia old fields and road sides. Where the forest floor is thick, white spruce has trouble germinating and surviving. Observations and plot data in Nova Scotia have found low white spruce regeneration levels in softwood sites despite having mature white spruce in the overstory and cones observed on the ground. These sites are usually dominated by mosses and have a thick forest floor (i.e., undecomposed organic matter). On the other hand, in stand canopies dominated by hardwoods with scattered mature white spruce, white spruce seedlings and saplings were found more frequently. These sites have thinner forest floors that are usually less than 2 cm and derived from hardwood leaf litter.

6.3. Vegetative Reproduction

White spruce is biologically capable of vegetative reproduction, although it is uncommon in Nova Scotia forests. Natural layering is observed in the exposed krummholz coastal and highland forests, particularly along active coastal edges where branches are buried by sand and seaweed (Fig. 6). However, the process is slow and uncommon even in these settings, with most trees originating from seed. Burns and Honkala (1990) report layering was only observed on the very northern limits of its range in Alaska and northern Canada probably as a means of maintaining the stand when sexual reproduction is limited or non-existent because of climatic limitations. Early seedling production of Highland white spruce at the Strathlorne Nursery involved extensive use of rooted cuttings during the late 1970s and 1980s (E. Quigley, personal communication, 2024). White spruce is readily grafted and commonly used for seed orchard establishment.

Fig. 6. Rootlet developing on buried branch in krummholz (left) and two attached white spruce stems on exposed krummholz roots, both observed at the north shore of Prince Edward Island.

6.4. Growth and Yield

Fernow (1912) describes the growth of white spruce, especially when the species "occupies readily the abandoned pastures near the coast, and there, in full enjoyment of light, grows as rapidly, or perhaps more rapidly [than red spruce]. A few measured white spruce showed diameter growth at the rate of 1 inch in four years. Balsam fir, which in some parts is erroneously called white spruce, shows about the same rate of growth. One inch in five to six years seems the rate for young second growth of this species on pastures" (p. 33).

Nova Scotia inventory PSP data have reported white spruce as tall as 26.4 m and 63.1 cm in diameter at breast height. From plots established for the FEC, the oldest tree was 203 years and found in the Cape Breton Highlands, while the tallest tree was 26.0 m and found on a floodplain in the Central Lowlands (Table 4). Many of the VTs with white spruce contained trees exceeding 100 years of age. The average age of 25 old field white spruce stands used in the FEC (Neily et al., 2023) was 48 years breast height age and ranged from 32 to 70 years old.

White spruce is most recognizable for its occurrences in pure stands established on old, abandoned farm fields that are common in Nova Scotia. Drinkwater (1957) estimated old field spruce amounted to over 200,000 ha (500,000 acres) in Nova Scotia. In fact, from 1921-1971 Statistics Canada (2022) reported 1,399,622 ha (3,458,541 acres) fewer in farmland. In the province, farmland is still being abandoned, thereby providing a continued opportunity for additional old field spruce. According to Statistics Canada (2022) farmland has decreased by 246,385 ha (608,830 acres) during the period 1971-2021. This reduction in farmland (Fig. 7) creates ample opportunity for reforestation of these abandoned old fields to white spruce forests. Fernow (1912) estimated cleared farmlands in Nova Scotia as amounting to 918,759 ha (2,270,304 acres).

Old-field spruce is unique in its silvical characteristics compared to forest-regenerated white spruce. Growth and regeneration characteristics of these stands have been the subject of studies by Drinkwater (1957) and Jablanczy (1969, 1979). Growth of white spruce once established on abandoned farmland is rapid, with average yields of 256 m^3/ha for 51-60 year old well stocked stands in his survey of 200 old-field stands. They averaged 48 m^2/ha in basal area (88% white spruce), 2,200 trees/ha, 16.5 cm in diameter at breast height (DBH) with height growth amounting to 15-25 cm/yr after 30 years of age. Mean annual increment of merchantable volume was 4.5 m^3/ha/yr. On average, these stands took six years to reach breast height and 18 of 87 became fully stocked after 10 years. Almost none of the stands had advanced regeneration due to heavy moss layers. Despite the fast growth, stands rapidly become stagnant and susceptible to bark beetles and other insects/diseases after 60 years of age (Johnson, 1986). Many old-field white spruce stands are clear-cut at this age due to decline.

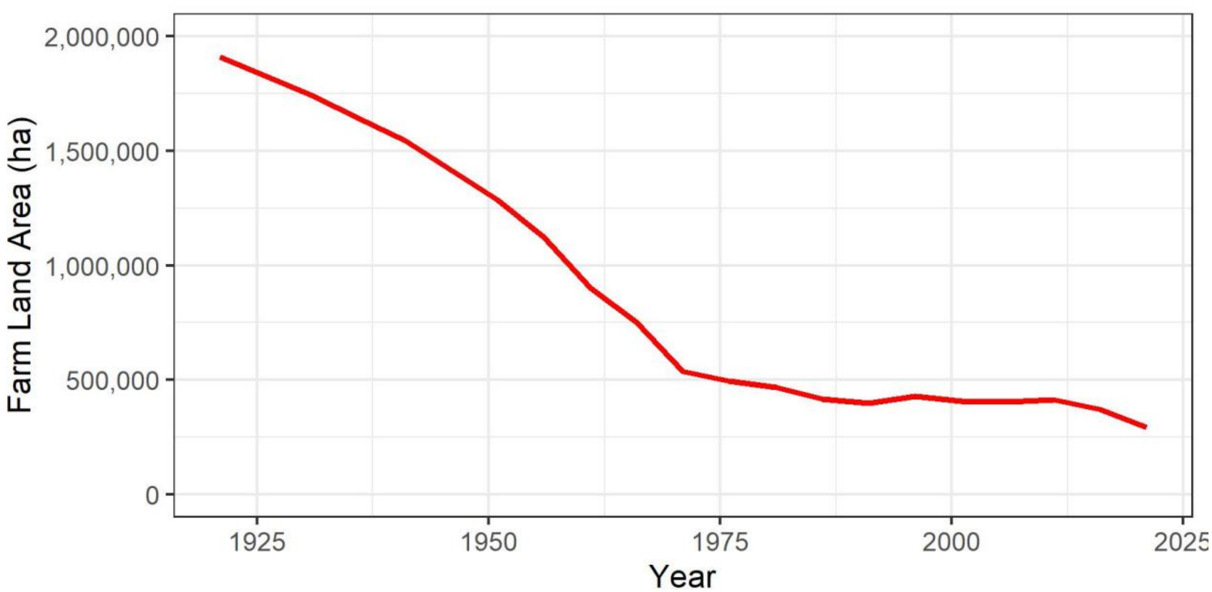

Fig. 7. Farmland area in Nova Scotia from 1920 to 2021 (Statistics Canada, 2022).

Once harvested by clear-cutting, poor regeneration results. This was attributed by Drinkwater (1957) to the heavy moss layers typically in the understory, the rapid invasion by grasses after harvesting, and the heavy slash resulting from harvesting the branchy old-field spruce. Jablanczy (1979) carried out a detailed survey of 97 stands covering 81 ha (200 acres), representing more than 8,094 ha (20,000 acres) of clear-cuts in the 1960-1970 decade in Eastern Nova Scotia. He found 30% of the 1-19 year-old cutovers were adequately stocked (greater than 75%). Forty percent of the stands had less than 50% stocking. On average, total stocking was 54%, with softwood stocking at 32% and hardwood stocking at 22%. Advanced regeneration stocking was 16% overall, with 13% softwood advanced stocking and 2% hardwood advanced stocking. Wall (1975) stated that a regeneration survey of several forest types after five years showed that 90% of the area needing planting was cleared old-field white spruce. A regeneration survey of 374 cut-overs (868 stands) carried out province wide on five-year-old clearcuts between 1994-1995 showed similar results to earlier surveys (Stewart & Quigley, 2000). While 90% of stands were adequately regenerated with an average 24,000 stems/ha, old field white spruce stands were the only pre-harvest vegetation type that was consistently understocked with regeneration five years after the clear-cut (Stewart & Quigley, 2000).

These studies indicate the poor regenerating capacity of old-field white spruce in clear-cut harvests and their suggestions for improvement include partial cutting and planting. In Nova Scotia, partial cutting has been tried without success while planting has been successful for these sites if competing vegetation is controlled. Roller (1978) reported white spruce survival levels at nearly 70% in Nova Scotia white spruce plantations established between 1966-1970. O'Keefe et al. (1994) showed planted white spruce stocking averaging 74% on 9–14 year old plantations established in 1989-1991. Old field white spruce cut-overs have a high hazard for seedling debarking weevil infestations (*Hylobius congener*) in the first 2-3 years following harvest. They will kill newly planted seedlings and can devastate plantation survival if sites are planted too soon, which may have affected the plantation stocking averages reported above.

6.4.1. Life History – Sapling and Pole Stages to Maturity

White spruce exhibits strong apical dominance of the terminal shoot and therefore has a conical crown form. Crown form may deviate substantially because of variation in the growth of lateral branches related to tree and branch age, damage, or growing conditions. The most significant deviations occur in high-wind areas where marginal growing conditions can result in shrub-like trees called krummholz.

During the juvenile phase, trees will grow continuously if all growth factors are within the optimum range. This is called "free growth". In older trees, shoot growth is determinate; that is, the annual complement of needles is pre-formed in the over-wintering bud (Burns & Honkala, 1990). The formation of the following year's buds in Nova Scotia begins in early May with the initiation of the first bud scales. Needles for the next growing season are initiated in August after the period of shoot elongation. On productive forest sites, visible signs of shoot growth (i.e., flushing) are first observed in early May to early June (Burns & Honkala, 1990).

The time of flushing is primarily temperature dependent and therefore varies with the weather. The number of degree days accumulated at the time of flushing may vary from year to year, indicating that more than air temperature controls the initiation of the annual shoot-growth cycle (Burns & Honkala, 1990). Within a stand, there can also be as much as a three-week difference among individual trees. The period of shoot elongation is short. In Nova Scotia, the period from flushing until the terminal leader completes elongation ranged from 26 to 41 days, among individual trees. Shoot growth is generally completed by the end of June. The cessation of shoot growth is more dependent on photoperiod than on temperature (Burns & Honkala, 1990). Cambial activity in Nova Scotia begins in May. Most bole growth is completed by September.

White Spruce has higher nutrient requirements than other native Nova Scotia softwood species (Stiell, 1976). Species stock type studies in Nova Scotia also suggest white spruce tends to have higher nutrient concentrations and thus higher nutrient demands than other spruce species (Table 2). It is theorized that higher nutrient demand may result in decreased long-term yields for white spruce growing in plantations on lower fertility sites (Steenberg et al., 2025a). However, even on the medium-to-rich sites used for the Nova Scotia species stock type trials, foliar nutrient levels for white spruce were below desirable levels (Table 3) based on optimum concentrations reported by Quesnel et al. (2006). This suggests the possible need for white spruce nutrient management on higher fertility sites as well.

Table 2. Nutrient content data for spruce species grown on two medium-to-rich trial sites in central Nova Scotia (Keys & Bockstette, 2023). The WS:RS and WS:BS variables are the ratio of nutrients present in white spruce compared to red spruce and black spruce, respectively.

Species	N	C (%)	N (%)	P (g/kg)	Ca (g/kg)	Mg (g/kg)	K (g/kg)
Bark							
NS	4	50.3	0.27	0.42	5.66	0.69	1.78
WS	2	49.4	0.26	0.53	7.46	0.73	2.29
RS	2	53.1	0.20	0.33	3.44	0.42	1.33
BS	1	51.7	0.22	0.43	5.83	0.59	1.79
WS:RS			1.3	1.6	2.2	1.8	1.7
WS:BS			1.2	1.2	1.3	1.2	1.3
Foliage							
NS	4	48.9	0.92	1.27	1.85	0.73	5.52
WS	2	49.9	0.89	1.24	1.68	0.66	4.72
RS	2	49.3	0.74	1.14	2.11	0.77	4.16
BS	1	49.3	0.73	1.12	1.17	0.57	3.99
WS:RS			1.2	1.1	0.8	0.9	1.1
WS:BS			1.2	1.1	1.4	1.1	1.2
Wood							
NS	45.4	0.04	0.09	0.39	0.09	0.53	45.4
WS	49.4	0.05	0.07	0.42	0.09	0.42	49.4
RS	44.8	0.04	0.08	0.33	0.07	0.62	44.8
BS	48.4	0.03	0.06	0.48	0.09	0.29	48.4
WS:RS			1.3	0.9	1.3	1.3	0.7
WS:BS			1.5	1.2	0.9	1.0	1.5
Branch							
NS	4	50.2	0.30	0.41	2.35	0.51	1.46
WS	2	49.8	0.20	0.28	2.36	0.35	0.84
RS	2	49.9	0.22	0.27	2.03	0.36	0.93
BS	1	50.8	0.23	0.35	1.80	0.40	0.94
WS:RS			0.9	1.1	1.2	1.0	0.9
WS:BS			0.9	0.8	1.3	0.9	0.9

Table 3. White spruce foliage nutrient data from Table 2 with optimal concentrations for boreal white spruce reported by Quesnel et al. (2006).

Concentration	N (%)	P (g/kg)	Ca (g/kg)	Mg (g/kg)	K (g/kg)
From Table 2	0.89	1.24	1.68	0.66	4.72
Optimum	1.2	1.9	6.5	1.0	7.3
Minimum	1.1	1.6	4.3	nd	5.5
Maximum	1.4	2.3	8.6	1.3	9.2

White spruce is more prevalent in the eastern Nova Scotia counties of Pictou, Antigonish, and Guysborough and on Cape Breton Island whereas naturally regenerated red spruce occurs less frequently (Figure 2). Mixed-species stands that normally consist of red spruce in central and western Nova Scotia contain white spruce as a cohort on Cape Breton Island and eastern Nova Scotia. In the provincial forest inventory for the period 1979-1989 (NSDNR, 1991), white spruce accounted for 23% of the softwood merchantable volume in eastern Nova Scotia (i.e., Pictou, Antigonish, and Guysborough Counties and Cape Breton Island) and only 8% and 7% respectively for central and western Nova Scotia. A similar trend was observed in an earlier provincial inventory (Hawboldt & Bulmer, 1958), where white spruce volumes were highest in the Cape Breton Island counties (32-34% of all merchantable volume), lowest in central and western counties, excluding Annapolis and Kings (2-8%) and intermediate in eastern counties and the counties of Annapolis and Kings (12-16%). Perhaps the larger amount of abandoned farmland in Annapolis and Kings accounts for this aberration in western Nova Scotia.

NSDNR has extensive systems of both inventory and research PSPs that form the foundation for growth estimates for white spruce over different site and cultural scenarios as quantified by site index, land capability (LC), and silviculture timings and extents. These estimates can be found in the province's Nova Scotia Growth and Yield (NSGNY) model (NSDNR 1993a; MacPhee & McGrath, 2006; O'Keefe & McGrath, 2006; Steenberg et al., 2023). A more recent NSDNR study showed that when comparing site index and LC across different softwood species in species stock-type trial plantations, white spruce tended to have slightly higher values than red spruce (though not statistically significant) and had lower values than other commonly planted softwood species except for black spruce (Table 4; Steenberg et al., 2025a).

Table 4. Site index and land capability for commonly planted softwood species, showing mean values, standard deviation (SD), and sample size (N, number of plots) from Steenberg et al. (2025a).

Variable	N	Site Index Mean	SD	LC Mean	SD
RS	20	17.58	1.45	6.53	0.81
WS	17	18.41	2.43	6.15	1.23
BS	16	17.06	2.61	5.56	1.29
NS	12	20.91	2.40	8.48	1.42
WP	12	19.68	1.46	7.29	0.81
RP	14	21.78	1.33	8.91	0.76
BF	15	20.14	2.07	7.06	1.01

Data from the FEC plots was also used to form white spruce productivity estimates (m^3/ha/yr) for the ecosites where white spruce occurred (Neily et al., 2013). According to Neily et al. (2013), white spruce LC values are estimated to range from 5.5 to 8.0 m^3/ha/yr for the Acadian Forest ecosites where it naturally occurs. These ecosites include the zonal ecosites AC10, AC11, AC13, and AC14, as well as the transitional ecosites AC9, AC16, and AC17. On Maritime Boreal ecosites, LC estimates for ecosites MB5, MB6, MB8, and MB9 range from 4.0 to 6.5 m^3/ha/yr.

Site index and LC quantify the productivity of sites in Nova Scotia. A direct translation from LC to site index and vice versa can be made based on the Nova Scotia Forest Field Handbook (NSDNR 1993b). Current LC values used in modelling, however, are derived from peak mean annual increment (m^3/ha/yr) in natural stands at the stand level with full stocking conditions. These LC values are generated by NSGNY and can differ slightly by species from site index because they contain species-specific volume estimates using different taper equations (Li et al., 2012). The NSGNY model can generate estimates over a range of sites for various silvicultural scenarios. A summary of some these estimates for specific situations are shown in Table 5 and further estimates can be determined by the direct use of the model.

Table 5. Yield estimates from NSGNY v2.1 for natural and managed white spruce stands.

SI4	**LC5**	**Age6**	**Height7**	**DBH8**	**MAI9**	**Age6**	**Height7**	**DBH8**	**MAI10**
NSGNY 2.11		*Natural Regeneration2*				*Plantation3*			
16	5.3	65	16	18	3.0	50	13	23	5.4
18	6.5	60	18	20	3.6	45	14	23	6.2
20	7.8	55	16	19	4.2	40	14	22	7.1

1 https://novascotia.ca/natr/forestry/programs/timberman/growthyield.asp
2 Assuming 60% stocking at rotation
3 Assuming 80% stocking at rotation
4 Site index at breast height age 50 in metres of dominant height
5 Potential mean annual increment at rotation for 100% stocked naturally regenerated stands
6 Age at stump height where maximum merchantable mean annual increment is predicted
7 Average height in metres
8 Diameter at breast height (1.3 m) in centimetres
9 Mean annual increment in solid cubic metres per hectare per year assuming 60% stocking
10 Mean annual increment in solid cubic metres per hectare per year assuming 80% stocking

Naturally regenerated white spruce growth on average white spruce sites in Nova Scotia (e.g., LC of 6.5 m^3/ha/yr and site index of 18 m) reach peak mean annual increment (PMAI) at 60 years of age when average height will be 16 m, average DBH will be 18 cm, and yield will be 3.0 m^3/ha/yr at 60% stocking. On the richer ecosites AC10, AC11, AC13, or AC14 (e.g., LC of 8 m^3/ha/yr and site index of 20 m), the yield would be higher and achieving PMAIs sooner, typically at 55 years of age with heights of 16 m, DBH of 16 cm, and a yield of 4.2 m^3/ha/yr at 60% stocking (Table 5). The NSGNY Model does not estimate yields for Maritime Boreal ecosites. These ecosites are impacted by frequent high winds resulting in lower height growth rates. Despite this, white spruce growing on these windy sites, especially on the Cape Breton Highlands, are adapted to the winds and DBH growth rates are accelerated due to the reaction wood being formed in these situations. Yields can be comparable to the Acadian sites but with shorter trees and higher DBH growth rates for equivalent site fertility.

Note as well that NSGNY was updated recently and tends to generally predict slightly lower yields in softwood plantations (Steenberg et al., 2023). The model can also predict mortality in plantations that occurs after establishment, which is known to occur in white spruce plantations. The values in Table 5 do not include those stocking adjustments but they can be viewed in the model. Additionally, both the updated NSGNY and previous version (Table 5) do not account for gains in site index that is typically observed in plantations compared to natural stands. This is an important area of future research and model development.

It is noted that many natural white spruce stands have a much lower stocking than 60% of white spruce as they often grow in mixed-species stands. When the stocking of white spruce is intermixed with associates in lower portions, the yields of white spruce will be lower. When white spruce is planted, gains in yield can be made in several ways. Improved stock can be used with superior growth characteristics and competition due to non-crop species and crop density can be controlled. Table 5 shows white spruce plantation yields for unimproved stock at 80% stocking, controlled for competition, and planted to 2.4 m spacing (1,736 stems/ha). Rotations (i.e., age at PMAI) are lower compared to naturally regenerated stands and PMAI is higher, increasing from 3.0 to 5.4 m^3/ha/yr for stands growing on a site index of 16 m. PMAI increases from 4.2 to 7.1 m^3/ha/yr are realized for a site index value of 20 m.

When plantations are established from trees originating from improved stock, volume yields can be further increased by an estimated average of 25% in Nova Scotia (NSDNR, 2021). Currently, more detailed analysis of white spruce growth from the tree improvement program is being performed by NSDNR. Early results have shown increased tree volume growth of up to 70% (S. Bockstette, personal communication, 2024).

6.4.2. Rooting Habit

White spruce rooting is generally reported as shallow in Nova Scotia (Harrison, n.d.). White spruce dominated VTs (Neily et al., 2023) seldom exceed 45 cm in rooting depth, which is most likely a function of the province's shallow tills and parent materials. However, in Ontario, according to Burns and Honkala (1990), rooting depth in white spruce is commonly between 90 and 120 cm (36 and 48 in) with taproots and sinker roots descending to a depth of 3 m (10 ft). In Ontario sites, 85% of the root mass was in the top 0.3 m (1 ft), but on the most northern sites, large roots are heavily concentrated within 15 cm (6 in) of the organic-mineral soil interface. Lateral spread of the root system was reported to be as much as 18.5 m (61 ft) on sandy soils in Ontario, and lateral root extension was estimated at 0.3 m (1 ft) per year (Burns & Honkala, 1990). On old-field sites, white spruce can reach deeper soil depths (Neily et al., 2013) and lateral root spread, especially on open grown individuals, has been observed to be several meters.

Fine-root production in a Maine plantation was 6,990 kg/ha (6,237 lb/acre); 87% of this material was located in the top 15 cm (6 in) of soil. In an Ontario plantation, fine roots 0.25 cm (0.10 in) in diameter and smaller comprised about 10% (2,670 kg/ha or 2,382 lb/acre) of the total root biomass. In British Columbia, 67% of the fine root production in a mixed spruce-fir stand was in the forest floor and A horizon. The average depth of these horizons was 8.3 cm (3.3 in).

Information on the timing of root growth in white spruce is somewhat limited and mostly related to seedling growth in nurseries and establishment in young plantations. Tarroux et al. (2014, p. 294) concluded in their study on root development following planting that "Rapid establishment and early growth of trees is crucial for maximising plantation productivity and avoiding seedlings being quickly overtopped by competing vegetation.

The capacity of trees to absorb water is one of the most important factors that affect the speed of establishment of planted seedlings, and drought stress is often the main reason for mortality or growth stagnation of conifer seedlings. Planted trees access water by producing new roots." Deep planting of white spruce seedlings below the root collar increased root development leading to increased tree height and basal diameter growth in Quebec (Tarroux et al., 2014).

Roots begin active growth in the spring near the time of budbreak. Root growth takes place throughout the growing season from May until freeze-up in December. A number of factors affect root growth, including soil temperature, moisture availability, and photosynthesis in the current year. Root growth varies through the season related to the various phases of the growth cycles of the tree. It is greatly reduced during drought, which may affect white spruce's ability to regenerate in deep moss. Once cambium growth tapers off in late August, root growth increases through September then tapers off until dormancy in December. Late-season growth is dependent on photosynthesis during the current year and can be affected by the health and quality of the needles and rate of photosynthesis activities occurring in the tree. Root grafting appears to be fairly common in white spruce. In one study, about 27% of the trees had root grafts with other trees.

6.4.3. Reaction to Competition

White spruce is considered intermediate in shade tolerance (Burns & Honkala, 1990, Harrison, n.d.) and less tolerant of shade than some of its common associates (i.e., black spruce, red spruce, balsam fir, and sugar maple), though this varies depending on site and stand conditions. It can regenerate under some shaded conditions. At Five Mile Lake, Guysborough County, a healthy suppressed 4-m sapling in the understory of a tolerant hardwood stand was 52 years old. A white spruce seedling that was 33 cm in height in the same stand was 17 years old. It is possible that white spruce regeneration is more successful in the higher sunlight situations found under hardwood canopies as compared to softwood ones. It is also known that white spruce is more suited to high-nutrient conditions, as found in some hardwood and mixedwood cover types. Burns and Honkala (1990) state that white spruce can effectively release after 50-70 years of suppression. At Five Mile Lake, release from suppression at age 20 (4.8 cm DBH) was also observed in a 61 year old white spruce. At Hayden Road, Guysborough County, a 167 year old white spruce had been released at 90 years (6.4 cm DBH).

In recognition of white spruce having variable silvic and growth characteristics on different ecosites and/or forest groups, the Nova Scotia Silviculture Guide for the Ecological Matrix (SGEM; McGrath et al. 2021; McGrath et al., 2025) has incorporated these differences in the silvicultural prescriptions. White spruce is considered a long-lived, intermediate-to-tolerant (LIT) species in the SGEM for all but the Old Field, Highland, Coastal Boreal, and Planted Forest Groups. In these latter forest groups, white spruce is not considered a management option for late successional values. Field observations in this study and long-term NSDNR datasets found that advanced white spruce regeneration was low in softwood stands despite mature white spruce in the overstory and cones on the forest floor (NSDNR, 2025). Understory regeneration to white spruce was noted to be significantly higher in tolerant mixedwood and hardwood stands with a mature white spruce overstory component.

Inventory PSP regeneration data (i.e., seedlings/saplings less than 3.1 cm DBH in 10-m^2 subplots) from the most recent round of measurements in natural stands only were also summarized to look at natural regeneration patterns across FEC Forest Groups (Fig. 8 & 9). The data confirm the consistently smaller component of white spruce in natural regeneration layers, with highest observed composition percentages in highland and old field sites.

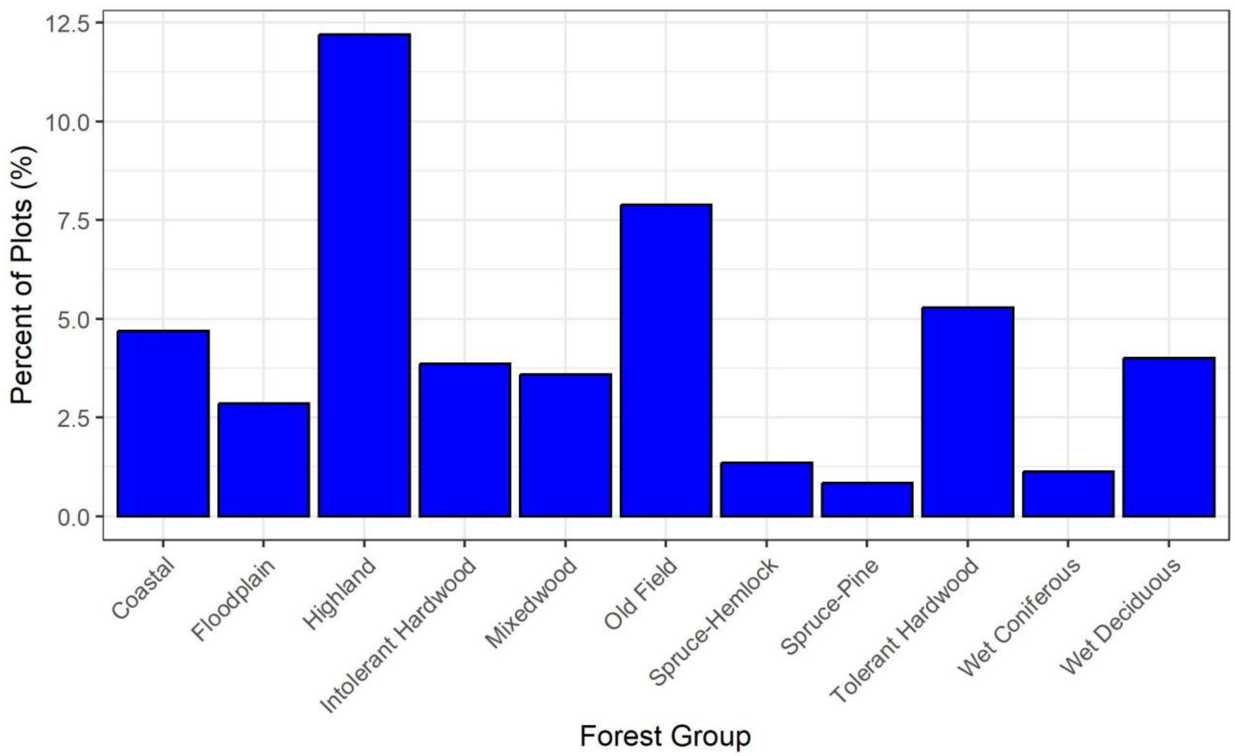

Fig. 8. Percent of inventory permanent sample plots with white spruce present in the regeneration layer (i.e., trees less than 3.1 cm DBH).

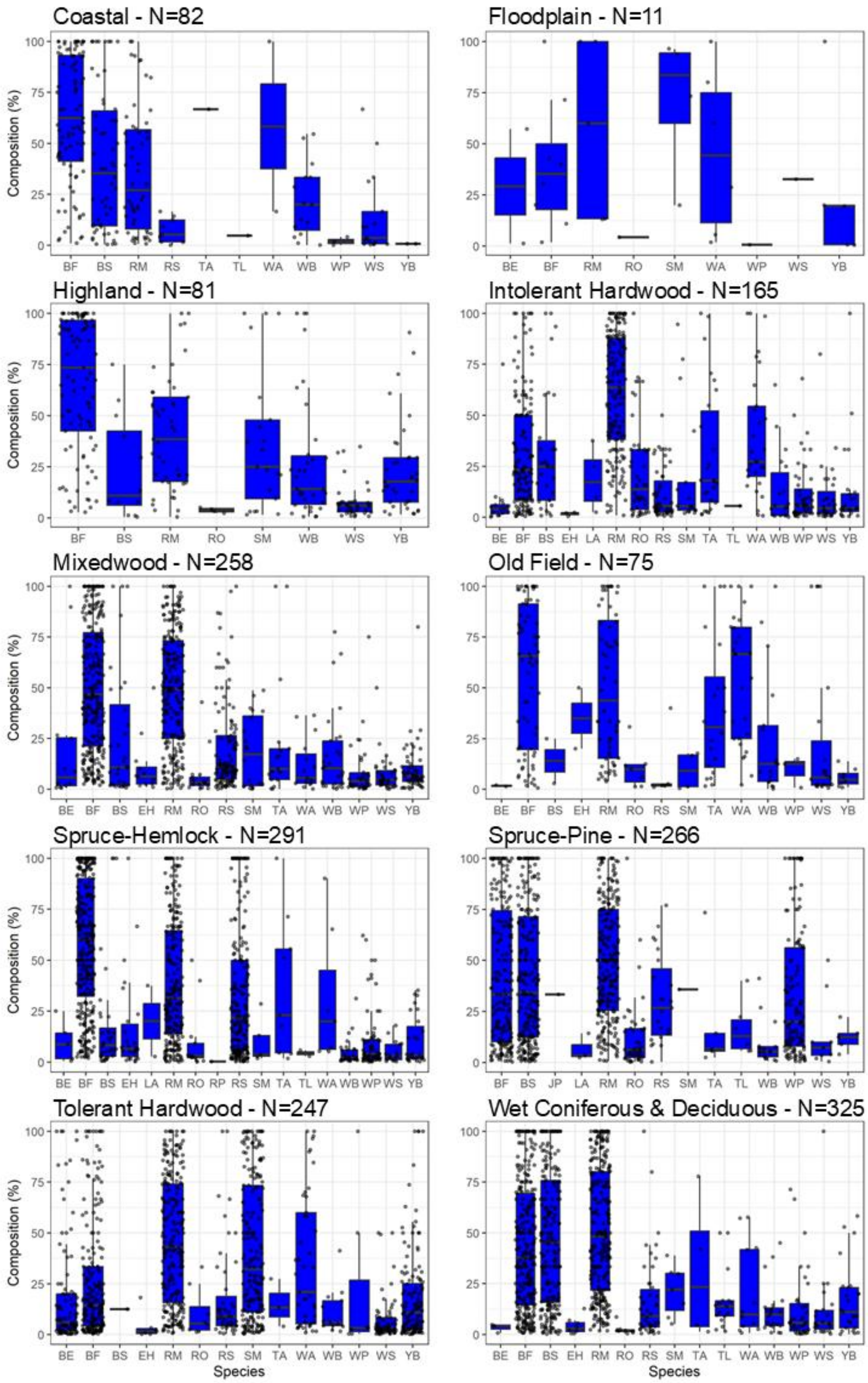

Fig. 9. Species composition of main commercial tree species in inventory permanent sample plots in the regeneration layer only (i.e., trees less than 3.1 cm DBH).

7. Ecological Role of White Spruce

Red maple has always been considered a generalist or species with a wide ecological niche within the Wabanaki-Acadian Forest Region, occupying most combinations of soil moisture and soil nutrient regimes from dry-to-wet and poor-to-rich ecosites. Using distribution and stand composition data from the PSP and FEC plot networks, it is apparent that white spruce may have a comparable pattern in ecological niche to red maple in its distribution (if not its abundance) within the region. Excluding old-field forests of white spruce, there are few occurrences of white spruce dominated stands in the Acadian Forest macrogroup. Aside from co-dominant stands of white spruce/red spruce in northern Nova Scotia and white spruce/balsam fir in eastern Nova Scotia, the species tends to be a minor component wherever else it may occur. However, in the Maritime Boreal macrogroup, white spruce can be a significant component, especially in the coastal forests along the Atlantic Coast. White spruce is recognized as a boreal species elsewhere in Canada's Boreal Forest Region and on the higher elevations of Cape Breton, white spruce is a consistent but typically minor component of the balsam fir dominated Maritime Boreal Forest.

The following subsections are categorized by general forest themes as informed by both the FEC Forest Groups and the ELC Ecoregions/Ecodistricts. Additionally, summaries of the provincial network of randomly located inventory PSPs are provided by FEC Forest Group. In 2017, NSDNR forest inventory staff began classifying PSPs using the 2013 FEC (Neily et al,. 2013), which is an important distinction because this report generally references the more recently published FEC (Neily et al., 2023; Keys et al., 2023). Each forest group is summarized by basal area and stand composition in relation to plot age. Only plots classified as natural (i.e., not managed/treated) are included in the analysis. Where a plot had more than one VT classified, the dominant one was used only. Note, however, that only the most recent FEC Forest Group is used in the data summaries below and plot age has a wide range of uncertainty, which are both limitations. Additionally, the plot ages presented in the data summaries are based on what has been observed/measured in the PSPs, not on the maximum ages possible for white spruce in these forest groups.

7.1. Coastal Maritime Boreal Forest

The Atlantic Coastal Ecoregion (800) and the Coastal Boreal Forest Group are dominated by white spruce, balsam fir, and black spruce. White birch and red maple are minor associates, especially where the coastal climatic influence is strongest. This forest is frequently disturbed by windstorms and hurricanes, resulting in primarily even-aged forests seldom exceeding 100 years of age. On the exposed headlands and offshore islands, white spruce is dominant as it can withstand the salt spray and breakage due to the powerful winds. The PSP data show that white spruce remains a relatively consistent component of plots over time in the Coastal Forest Group, despite the few older plots without a white spruce component (Fig. 10).

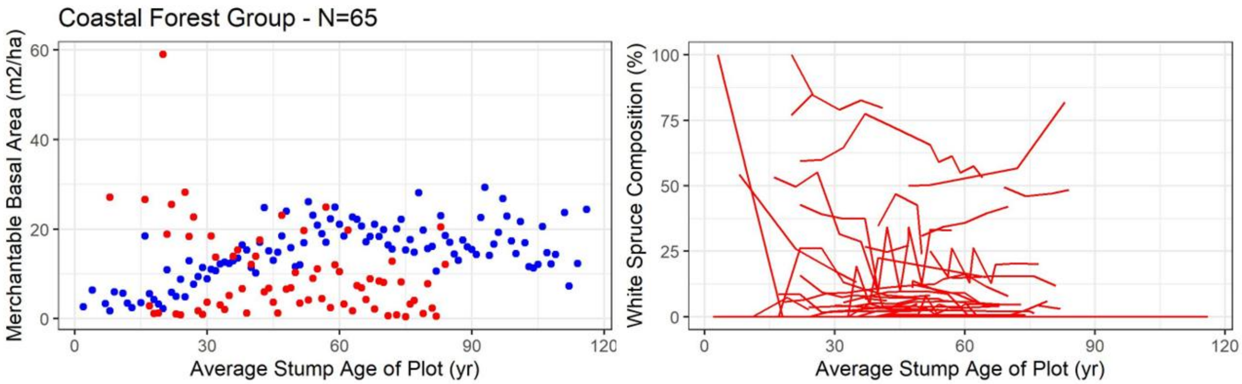

Fig. 10. White spruce (red) and other species (blue) merchantable basal area over plot age (left) and white spruce percent composition of merchantable basal area over plot age with lines representing individual plots over time (right) in the Coastal Forest Group.

7.2. Highland Maritime Boreal Forest

The Highland forests and Highland Forest Group are predominantly associated with the Northern Plateau Ecoregion (100), Cape Breton Highlands Ecodistrict (210), and the highest elevations of the Cape Breton Hill Ecodistrict (320). The even-aged balsam fir dominated forest (HL1) is frequently renewed by eastern spruce budworm epidemics (Taylor et al., 2020). In the absence of budworm mortality, the longevity of the fir forests is approximately 75 years. White spruce is a minor associate in this forest except on the crests and steep upper slope positions where it can dominate (HL2). Occasionally, it can be a co-dominant species with the balsam fir on ecosites associated with lower slopes along major highland streams. It also is a significant component of wet forests (WB2) associated with meadows and riparian zones along streams. White spruce is somewhat resilient to budworm and is often the only live retention tree species present after an outbreak. However, exposure and bark beetle reduce the numbers within 10-20 years (Steenberg et al., 2025b). Like the Coastal forests – the other forest group in the Maritime Boreal forest – the PSP data show a fairly consistent component of white spruce as the plots age (Fig. 11).

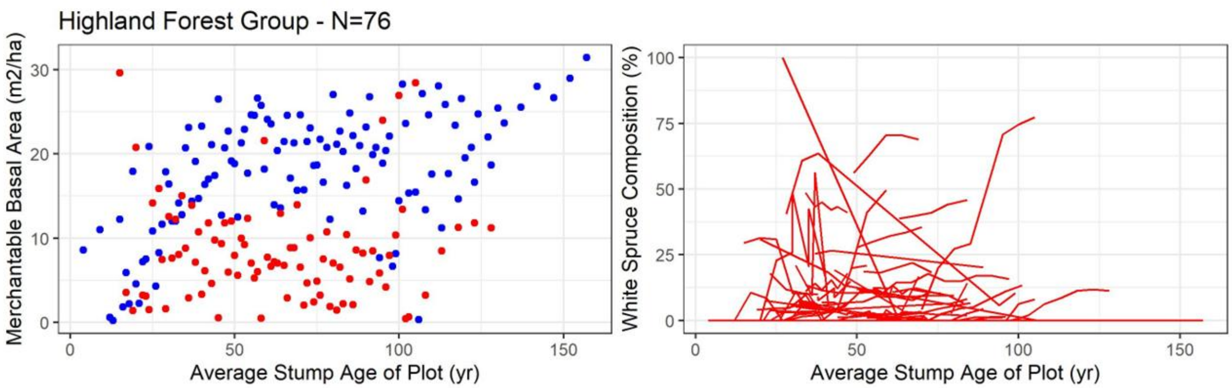

Fig. 11. White spruce (red) and other species (blue) merchantable basal area over plot age (left) and white spruce percent composition of merchantable basal area over plot age with lines representing individual plots over time (right) in the Highland Forest Group.

7.3. Eastern Spruce-Fir Acadian Forest

White spruce in the eastern mainland forests of Ecoregions 300 and 400 and on Cape Breton Island appears to occupy a similar ecological niche as red spruce in western and central Nova Scotia (i.e., Ecoregions 300, 400, 600, and 700). However, unlike red spruce it does not appear to fulfill the role of a dominant late successional species on similar ecosites (i.e., AC10 and AC11). At best, white spruce in these eastern forests (SH6) may be co-dominant in the canopy but it does not usually exceed 40% of the overstory composition. Balsam fir dominates these forests and under a frequent disturbance regime of wind/hurricane, insect, or senescence, stands tend to be two-aged at best with white spruce rarely exceeding 100 years.

Smith (1962) refers to the ability of some mixed stands to become stratified (i.e., ascendancy of better species to the upper strata). However, he mentions that there are some mixed stands, especially upland mixtures of spruce and fir that may or may not become stratified. He states: “The firs grow more rapidly than the spruces and reproduce more prolifically. However, any stratified mixtures that develop ultimately break up because the firs are relatively short-lived. The proportion of spruce thus gradually increases in the upper stratum but the advance regeneration that simultaneously begins to appear beneath the stand is predominantly fir. The result is that the fir is sometimes on top and sometimes under the spruce, but more often the two are intermingled at all levels” (p. 547).

7.4. Spruce Hemlock Acadian Forest

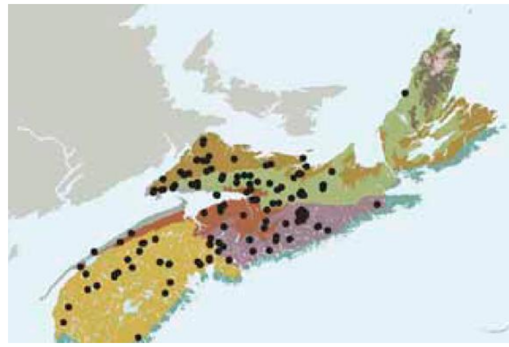

Fig. 12. Plot distribution for SH5 Red spruce – Balsam fir / Schreber's moss – Stair-step moss from Neily et al. (2023).

The occurrence of red spruce dominated vegetation types in Nova Scotia is best illustrated by the plot distribution map for the mid-successional SH5 (Red spruce - Balsam fir / Schreber's moss – Stair-step moss; Fig. 12). If the two vegetation types with a significant white spruce component (i.e., SH6, SH7) in the Spruce Hemlock Forest Group are excluded from the analysis, then only 21 of 334 plots or 6.3% had white spruce in any of the assessment layers and only 4.2% had white spruce sharing the overstory. The ecological role of white spruce in the red spruce – hemlock forest is most likely minor and perhaps a remnant of a time when cooler and moister climate conditions favoured white spruce.

As with the FEC data, the PSP data shows both a lower component of white spruce that declines well before stand/plot decline (Fig. 13). Note that the FEC Spruce-Hemlock Forest Group PSP data encompasses both spruce-fir (Section 7.3) and spruce hemlock (Section 7.4) Acadian forests described.

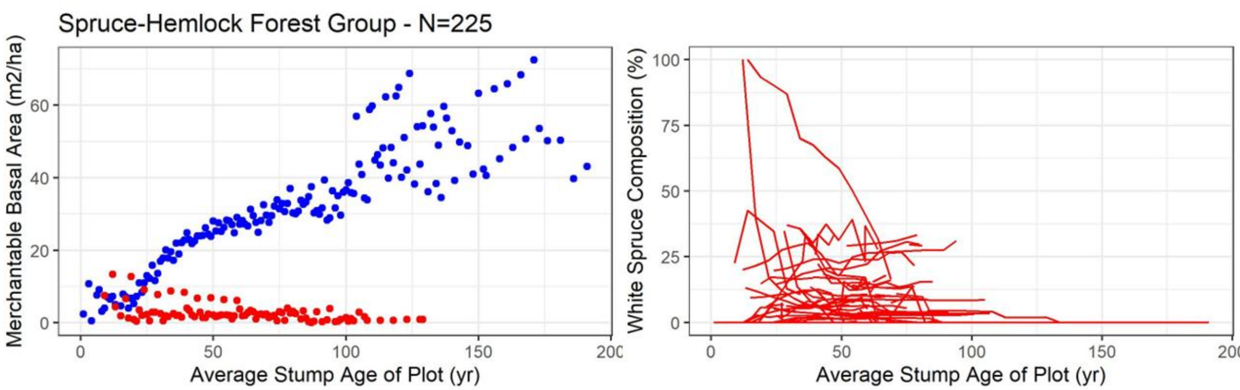

Fig. 13. White spruce (red) and other species (blue) merchantable basal area over plot age (left) and white spruce percent composition of merchantable basal area over plot age with lines representing individual plots over time (right) in the Spruce-Hemlock Forest Group.

7.5. Spruce Pine Acadian Forest

Soil nutrient levels are generally too low in the Spruce Pine Forest group to support healthy white spruce growth. However, the species was found in 21 of 218 plots (9.6%) with only 15 (6.9%) having it sharing the overstory. The PSP data also show low abundance of white spruce that is not persistent (Fig. 14).

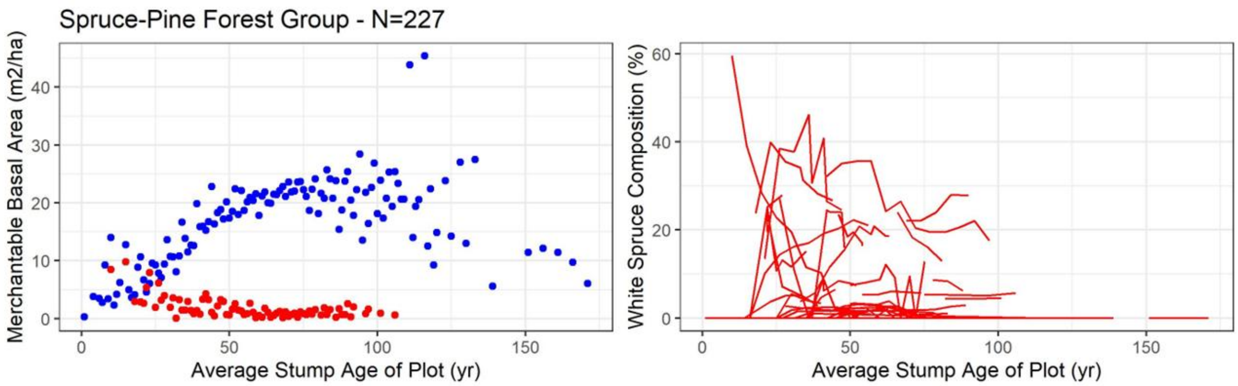

Fig. 14. White spruce (red) and other species (blue) merchantable basal area over plot age (left) and white spruce percent composition of merchantable basal area over plot age with lines representing individual plots over time (right) in the Spruce-Pine Forest Group.

7.6. Upland Tolerant Hardwood Acadian Forest

The reforestation of abandoned agricultural lands in the tolerant hardwood dominated uplands of Nova Scotia (i.e., Cobequid Hills, Pictou/Antigonish Highlands, Cape Breton Hills) suggests that white spruce, as a seed source, is either a minor component of these hardwood forests or occurs in less common ecosystems such as those associated with streams, wetlands, vernal pools, moist lower slopes, and/or seepages. This despite the fact that it is well known that white spruce dominates the shorter-lived old field VTs (Fig. 15).

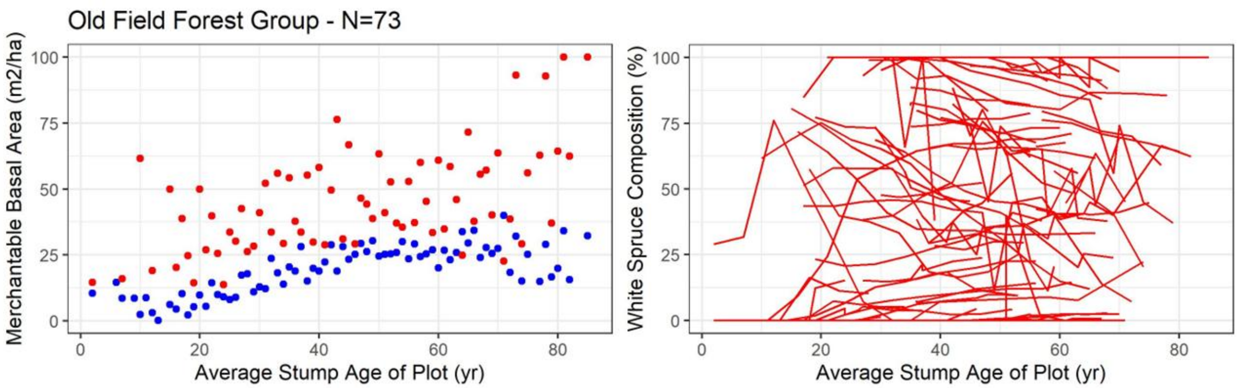

Fig. 15. White spruce (red) and other species (blue) merchantable basal area over plot age (left) and white spruce percent composition of merchantable basal area over plot age with lines representing individual plots over time (right) in the Old Field Forest Group.

Of the 356 FEC plots in the Tolerant Hardwood Forest Group, 43% had white spruce in any layer but only 10% had white spruce in the overstory and in these plots white spruce accounted for 2-7% of the overstory coverage. Recent field reconnaissance has revealed that white spruce regeneration under tolerant hardwood forests is shade tolerant. Furthermore, increment cores from overstory white spruce in these tolerant hardwood forests showed that white spruce once released can achieve normal growth rates. However, natural disturbances in tolerant hardwood forests are usually caused by wind/hurricane events resulting in individual and small patch disturbances with these conditions favouring the re-establishment or release of shade tolerant hardwood advanced regeneration. Only scattered small stands of white spruce are ever encountered in the upland hardwood forest and these are usually associated with shallow soils over bedrock or steep upper slopes. The PSP data confirm that white spruce is a small component of tolerant hardwood forests but indeed persistent in the regeneration and up until the oldest plot ages recorded (Fig. 16).

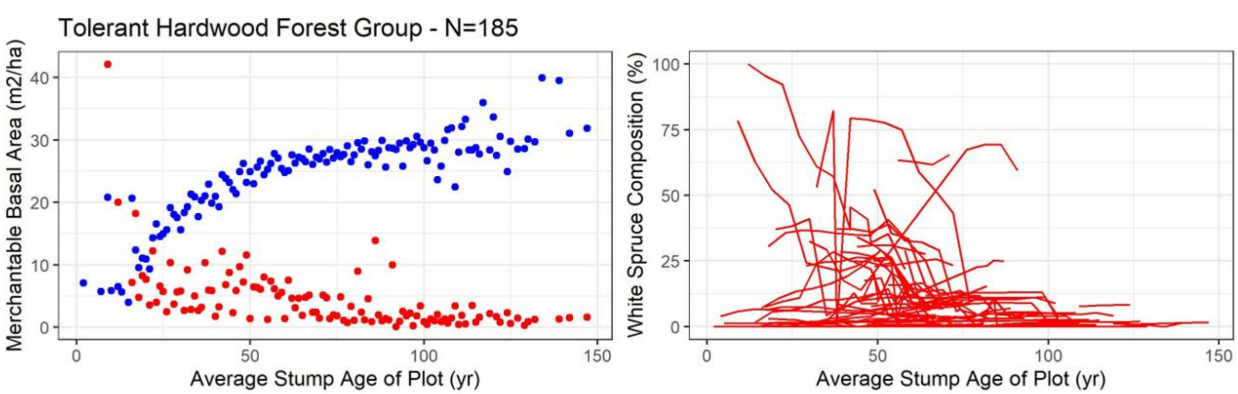

Fig. 16. White spruce (red) and other species (blue) merchantable basal area over plot age (left) and white spruce percent composition of merchantable basal area over plot age with lines representing individual plots over time (right) in the Tolerant Hardwood Forest Group.

7.7. Upland Tolerant Mixedwood Acadian Forest

FEC data show that shade tolerant mixedwood forests are dominated by red spruce in most of mainland Nova Scotia. Of the 148 plots for MW1 and MW2, only 12% had white spruce in any layer and only 5% had white spruce in the overstory. The occurrence of late successional white spruce / yellow birch shade tolerant mixedwood (MW5) is confined to the eastern mainland and Cape Breton Island, where red spruce is uncommon. The early-to-mid-successional MW6 has wider provincial distribution but is primarily an eastern Nova Scotia ecosystem. As determined from field reconnaissance, white spruce under mixedwood forests is shade tolerant. In eastern Nova Scotia on medium to rich ecosites (i.e., AC13, AC14), white spruce occupies a similar ecological niche as red spruce does in western Nova Scotia. Although there has only been limited sampling for white spruce longevity, FEC and PSP plots with white spruce on rich ecosites have aged individual trees at 130-163 years breast height age. PSP plots classified in the Mixedwood Forest Group show a fairly similar trend as Tolerant Hardwood (Fig. 17). The early-to-mid successional Intolerant Hardwood Forest Group can mature into a variety of other later-successional forest groups across a wide range of site conditions, though is more often found on zonal ecosites (Neily et al., 2023). PSP data summaries are included here for reference, and indeed show that these forests are shorter-lived and have a small but persistent component of white spruce (Fig. 18).

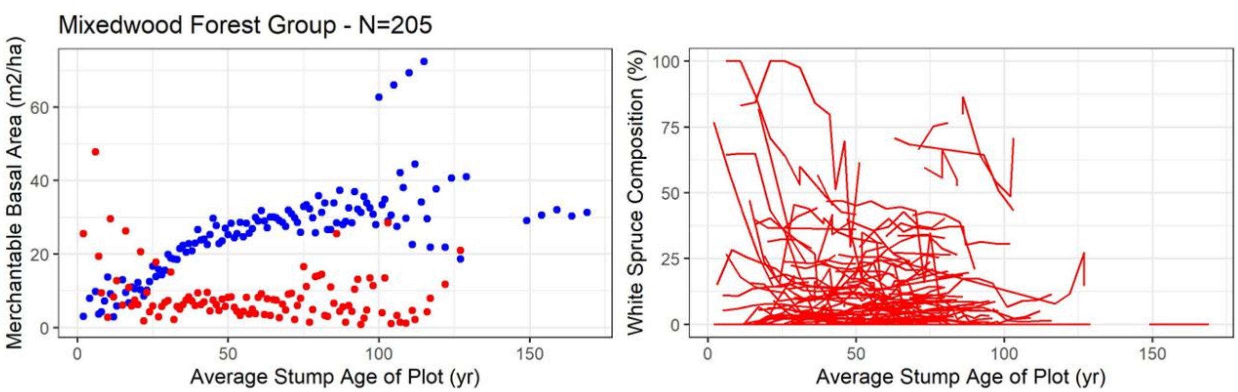

Fig. 17. White spruce (red) and other species (blue) merchantable basal area over plot age (left) and white spruce percent composition of merchantable basal area over plot age with lines representing individual plots over time (right) in the Mixedwood Forest Group.

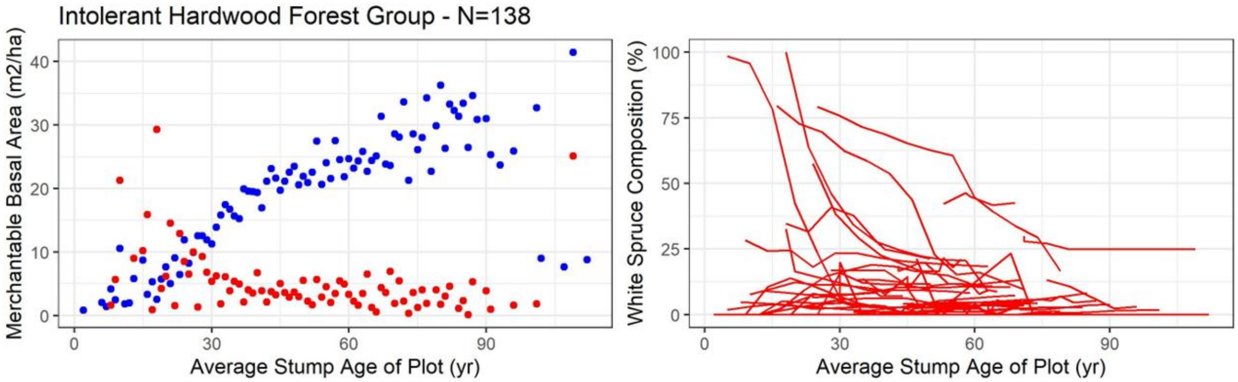

Fig. 18. White spruce (red) and other species (blue) merchantable basal area over plot age (left) and white spruce percent composition of merchantable basal area over plot age with lines representing individual plots over time (right) in the Intolerant Hardwood Forest Group.

7.8. Floodplain Forests

Abandonment of pastures and fields associated with floodplains along both large and small watercourses supports the hypothesis that the species is early successional. Typically, these sites once left to their own recovery follow a path of shrubs (i.e., alders, hawthorns, black cherry) before establishing white spruce and/or white ash. This is confirmed by the few existing PSPs in the floodplain forest group, where white spruce abundance is almost comparable to old field sites (Fig. 19).

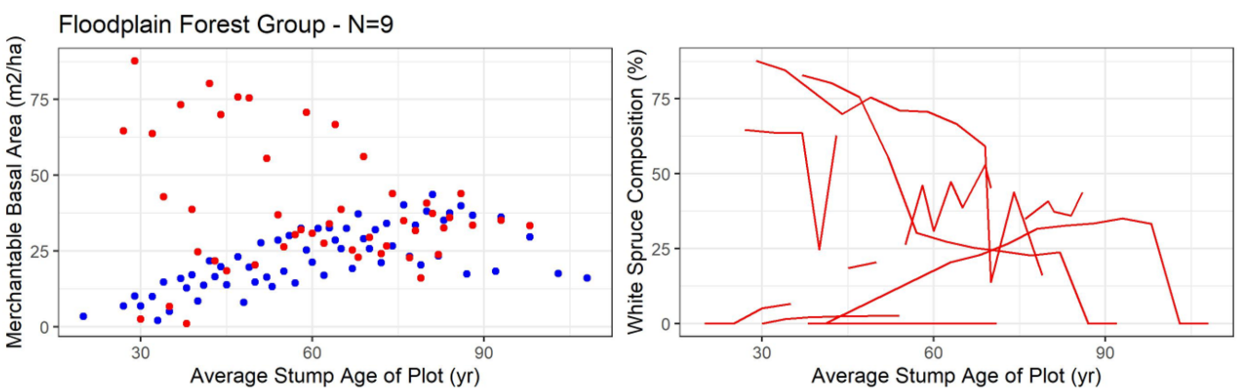

Fig. 19. White spruce (red) and other species (blue) merchantable basal area over plot age (left) and white spruce percent composition of merchantable basal area over plot age with lines representing individual plots over time (right) in the Floodplain Forest Group.

7.9. Wet Forests

White spruce in the Wet Boreal Forest Group occurred in 52.6% of the 19 FEC plots as an overstory species, suggesting that these wet forests may provide seed sources for reforesting adjacent uplands after stand level disturbances. Wet Coniferous, Wet Mixedwood, and Wet Deciduous are the three Forest Groups encompassing wet forests in the Acadian Forest macrogroup. There were 298 FEC plots used to define these groups and of that number, 18.1% had white spruce and 9.1% with white spruce in the overstory. Compared to adjacent upland forests, in particular Tolerant Hardwood and Tolerant Mixedwoods, the white spruce component in these wet forests is typically higher and is most likely a seed source for when significant stand-level disturbances occur in these upland forests. Recall that the PSPs use the 2013 FEC, so no distinction between Acadian and Maritime Boreal forests are made and only Wet Coniferous and Wet Deciduous Forest Groups are classified (Fig. 20 & 21). However, within these two forest groups, white spruce is indeed more prevalent than in most others, though fewer examples of white spruce in older Wet Coniferous PSPs were observed.

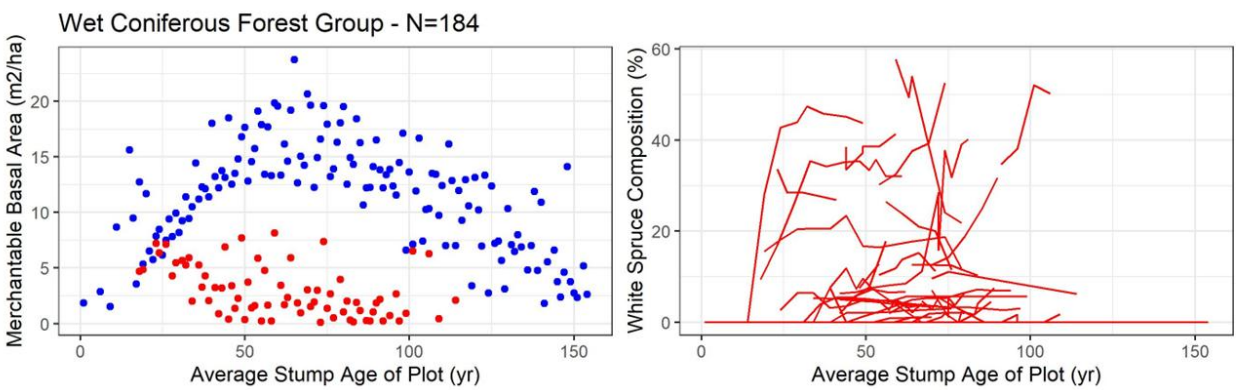

Fig. 20. White spruce (red) and other species (blue) merchantable basal area over plot age (left) and white spruce percent composition of merchantable basal area over plot age with lines representing individual plots over time (right) in the Wet Coniferous Forest Group.

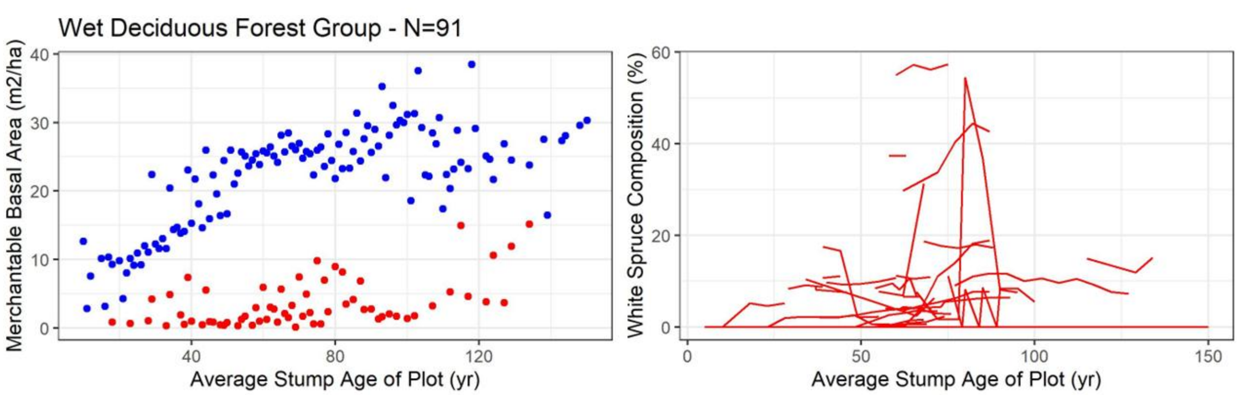

Fig. 21. White spruce (red) and other species (blue) merchantable basal area over plot age (left) and white spruce percent composition of merchantable basal area over plot age with lines representing individual plots over time (right) in the Wet Deciduous Forest Group.

8. Successional Personalities

White spruce is a generalist species that is broadly distributed across the Acadian and Maritime Boreal Ecoregions of Nova Scotia. It occurs on most ecosites and is associated with most of the province's vegetation types and tree species. However, it seems to play several different ecological roles depending on site conditions, which cause it to exhibit distinct silvical personalities reflective of the setting. These include acting as a primary succession pioneer of deforested sites, a mid-successional associate of low-to-medium fertility ecosites, and as a late successional climax associate on richer hardwood and mixedwood ecosites. The latter category is generally referred to as a LIT species (McGrath et al., 2021; 2025). In Maritime Boreal forests, these roles are simplified by low species diversity within vegetation communities compared to the Acadian forests.

8.1. Pioneer Personality

White spruce is perhaps best known for its formation of old field or pasture spruce forests (OF1), which are a unique and familiar part of Nova Scotia's rural landscape. Through the 1900s, nearly 400,000 ha of farmland (10% of the province's current forest landbase) was abandoned and regenerated to white spruce forests (OF1). Cleared for farming during the 1800s, most were formerly tolerant hardwood and mixedwood forests on moderately rich, fresh-to-moist ecosites (AC13, AC14, AC10, and AC11) common in the upland ecodistricts. Once abandoned, most fields in eastern and central Nova Scotia regenerate to almost pure stands of white spruce within a couple of decades. There are also several other old field vegetation types (OF2, OF3, OF5, and OF6) in which white spruce is an associate.

Left fallow, abandoned fields slowly develop a variety of herbaceous and shrub species among the grasses, including goldenrod, aster, spirea, rose, bayberry, raspberry, blueberry, and alders. Within a couple of decades, scattered trees establish on the edges and then spread across the fields in quick succession. The seed source for this process may begin with the small population of mature white spruce that persists in sheltered mid- and lower-slope valleys and seeps, although that has not been confirmed. Scattered white spruce that establishes in the old fields begins to produce seed at a fairly young age (e.g., 10 years) providing plentiful seed to complete the reforestation process.

Old field white spruce forests tend to be relatively even-aged stands, with closed canopies at maturity resulting in needle carpet and mossy forest floors with little vegetation or woody debris. Past ploughing eliminates natural mound and pit microtopography, leaving smooth forest floors with an organically enriched upper soil horizon (i.e., Ap horizon). They establish at fairly low density compared to naturally disturbed forests so that many trees have limby, large-crowned, open-grown form, and typical stem exclusion processes are reduced, leading to minimal development of woody debris. Tree growth tends to be rapid and mature stands often have high volumes, although sawlog quality is often poor due to limbs/knots.

Pioneer white spruce forests are short-lived and subject to rapid mortality around 60 years of age. They will transition from a healthy, vigorous appearance to an expanse of dead trees in a very short time, often surprising landowners and managers. Bark beetles are usually the primary agent, although defoliating insects (e.g., tussock moth, spruce budworm) and fungal diseases can play a role. Unlike almost all other forest types in Nova Scotia, old field white spruce forests that have either died naturally or been harvested are very slow to regenerate, and they do not tend to regenerate back to pure white spruce. These sites eventually regenerate with mixes of red maple, white birch, aspen, balsam fir, and white spruce (OF4, OF5), starting the slow transition back to their more natural forest types. It may take several generations to restore climax communities, pit and mound microtopography, and typical upper soil horizons.

In addition to old fields, a variety of other deforested sites that occur undergo primary succession leading to nearly pure white spruce stands. This includes naturally disturbed floodplains, coastal headlands, shallow-to-bedrock outcrops within hardwood uplands, as well as roadsides and other human clearings. Of interest is the relatively recent development of “moose meadows” on the Cape Breton Highlands, following the 1980s spruce budworm outbreak. These sites have remained in a grass stage for several decades and may be candidates for white spruce primary succession, although there is no evidence for that yet.

Pure white spruce stands are a unique phenomenon associated with primary succession and their current distribution is an unnaturally high reflection of historical land use. This forest type is likely to decline as farmland abandonment decreases, although plantations may allow pure white spruce forests to persist. Typical FEC VTs for pioneer, early successional white spruce include OF1, CB2, CB5, CB6, FP6, and HL2.

Primary succession white spruce forests provide some habitat value. Examples include habitat for red squirrels, chantarelle mushrooms, ants, cavity trees, pileated woodpeckers, and many mammals common in rural landscapes using the forest/field interface (e.g., fox, racoon, skunk, groundhog, mice/vole, deer, crow nesting/roosts, and hawks). The habitat value is often enhanced by apple trees, rock walls, and stone piles from past agriculture. In natural settings, pioneer white spruce forests will be used by turtles and other riparian species along floodplains while in ocean headlands and islands they provide valuable nest, roosting, and perching habitat for a wide range of bird species.

8.2. Mid-Successional Personality

White spruce is endemic across most of the Acadian and Maritime Boreal ecosystems in the province, where it is usually a component of early and mid-successional forests across all but the most nutrient poor ecosites. In its mid-successional role, it associates with a wide range of species, usually as a minor stand component in lower fertility mixedwood and intolerant hardwood stands, and a medium-to-dominant component of lower fertility softwood forests. These forests are typically even aged and will undergo renewal or transitions at maturity. The species appears to have difficulty regenerating on mossy microsites. The longevity of white spruce in these forests is longer than pioneer forests, typically at 75-100 years. While it will regenerate at stand renewal, it does not appear able to support a LIT/climax role of supporting uneven-aged development on the lower nutrient ecosites. Some examples of VTs that represent this personality include:

- Coastal: CA2
- Floodplain: All VTs excluding FP6
- Karst: KA4
- Intolerant Hardwood: IH1, IH3, IH4, IH5, IH6, IH8, and IH9
- Mixedwood: MW7, MW9, MW10, MW11
- Old Field: OF2, OF3, OF4
- Spruce-Hemlock: SH6, SH7, SH8
- Spruce-Pine: SP9, SP10
- Wet Coniferous: WC6

8.3. Late-Successional (Climax) Personality

White spruce has the ability to perform as a climax species on moderately rich, fresh-to-moist ecosites and rich wet edaphic ecosites. In these settings, a variety of mixedwood, tolerant hardwood, karst, and wet deciduous vegetation types will develop uneven-aged climax forests that include a relatively low composition of white spruce in the seedling, sapling, and mature stages. White spruce has a lower shade tolerance than some of the most tolerant LIT species but is able to regenerate and persist for decades in moderately shaded understories and will respond well to release after many years of suppression. Some examples of VTs that represent this personality include:

- Karst: KA1, KA2, KA3
- Mixedwood: MW3, MW4, MW5, MW6, MW13
- Tolerant Hardwood: All VTs
- Wet Deciduous: WD1, WD3
- Wet Mixedwood: WM1, WM2, WM4, WM5

Age measurements in PSPs and FEC plots have recorded mature white spruce between 150-200 years, often with evidence of release following early years of suppression. Healthy understory seedlings and saplings of 30-300 cm in height have been measured at 30-60 years. White spruce is an important but easily overlooked component of these climax forests. It can form large super canopy trees and snags that add significantly to habitat diversity, particularly in hardwood dominated ecosystems where small white spruce patches and individual trees can support small mammals, birds, and cavity nesters that would not otherwise be found in the stands. This may also provide some isolated island habitats attractive to interior species. It is common to find squirrel middens, pileated woodpecker cavities, and bird nests among these large white spruce. During field reconnaissance for this study, an instance of heavy grazing of honey mushrooms (Armillaria ostoyae) fruiting on dead white spruce was observed, likely by flying squirrel.

8.4. Highland/Coastal Maritime Boreal

Cape Breton Highland and Coastal Maritime Boreal Forest ecosystems have less complex tree communities than most of the Acadian Forest ecosystems, which simplifies successional processes. The pioneer role leading to establishment of pure white spruce forests occurs, but the prevalence is much reduced and mostly confined to natural settings due to a lack of past farming, although many coastal spruce forests show evidence of past land clearing for grazing. It is possible that the extensive moose meadows that currently dominate the northern extent of the Cape Breton Highlands may transition to these types, although that is uncertain at present.

Most of the Maritime Boreal forests have an even-aged structure and are dominated by balsam fir, black spruce, white spruce, and/or larch. White spruce is found across all ecosites ranging from poor to rich and wet to dry, where it is usually in a mid-successional role with other conifers, particularly balsam fir, in stands that undergo stand initiating renewal on periods of 60-90 years. White spruce is more resistant to defoliators than balsam fir and many may survive budworm outbreaks, providing some mature habitat for a period before wind and bark beetles complete the renewal process.

On moderately rich and rich fresh-to-moist sites in the Highlands, mixedwood climax forests of birch and balsam fir are supported in which white spruce is an important but minor component. In these settings, spruce longevity may reach over 125 years in unique old growth (HL3, HL4), where white spruce is able to regenerate, persist, and emerge from shaded understories. There are also several edaphic climax forests in which white spruce longevity may exceed 100 years. The Maritime Boreal Highland forests host many special habitats and species at risk, including Bicknell’s thrush, lynx, marten, lichens, and many coastal birds.

The Highlands support a climax white spruce/ balsam fir (WB2) forest on rich wet sites (MB7) with longevity of 100-125 years in mostly a two-aged structure. Coral lichen, an old growth indicator, is often abundant in these ecosystems and it is likely that a variety of stubble lichen, which are old growth associates, are also present. Perhaps the most unique climax forest is the krummholz found on extremely exposed high-elevation and coastal sites. These dense stunted thickets are dominated by balsam fir with moderate levels of white and/or black spruce as well as a variety of shrubs. Succession is patchy and trees can exceed 100 years in the harsh settings.

9. Insects and Disease

Climate change adds uncertainty regarding the level of insect and fungal introductions to the province from southern regions of North America. However, at this time nothing is apparent that could arrive from southern regions that may be enhanced. The unintended introduction of invasive species due to human actions such as entries from foreign regions at container ports is always a risk. Climate change also has the potential to intensify the frequency and duration of fungal attacks and may have significant consequences regarding mortality. Summers with prolonged periods of high humidity enhance the potential for fungal impacts on foliage, which if repeated over several seasons will cause decreased growth and potential mortality. Nova Scotia's field guide for pests of the Acadian forest (NSDNR, 2014) provides further information regarding the insects discussed below. The Canadian Forest Service (CFS) online publication, *Trees, insects, mites, and diseases of Canada's forests* (CFS, 2024), is another source of information.

9.1. Primary Insects

Eastern Spruce Budworm (*Choristoneura fumiferana*)

Typically, defoliation and mortality of white spruce has been attributed to its association with the much more susceptible balsam fir. However, significant defoliation occurred in old field white spruce forests in the Annapolis Valley in the early 1970s. Recent observation during sampling on Cape Breton Island has noted advanced instar stages under intact bud caps on white spruce, suggesting that perhaps white spruce provides protection against predators during early population build-up.

Eastern Spruce Beetle (*Dendroctonus rufipennis*)

The spruce beetle has long been known to decimate forests of white spruce originating on abandoned agricultural lands in Nova Scotia with mortality usually starting around 50 years of age. Not much is known about beetle losses in trees associated with the natural forest, although it could be implied to be similar to red spruce which seems to weaken around 150 years.

Whitemarked Tussock Moth (Orgyia leucostigma)

Stand level mortality occurred in Central Nova Scotia around 1995, but it is not expected again as natural predators are now keeping the population in check.

Yellowheaded Spruce Sawfly (*Pikonema alaskensis*)

This species has been observed causing mortality primarily in plantations of white spruce.

Hemlock Looper (*Lambdina f. fiscellaria*)

During an outbreak of hemlock looper, most softwood species including white spruce may experience mortality.

Brown Spruce Longhorn Beetle (*Tetropium fuscum*)

This invasive species arrived in Nova Scotia around 2000 at Point Pleasant Park in Halifax, causing mortality in red spruce in the Halifax area. Since then, it has not materialized to be a significant pest but could weaken trees enough to allow other stressors to cause mortality.

9.2. Secondary Insects

Although typically secondary agents, the following species could build populations sufficient to cause mortality if other stressors are also impacting the trees at the same time. Many times, the damage caused by these species is more aesthetic and of a landscape concern. On white spruce, these secondary insects include the whitespotted sawyer beetle (*Monochamus scutellatus*). Often this cricket-sized beetle can be seen crawling out of wood piles with its long antenna or a characteristic sound can frequently be heard, which is made by the larvae as they feed on the wood within their galleries.

White spruce can also be deformed by the white pine weevil (*Pissodes strobii*), as well as spruce budmoth (*Zieraphera canadensis*) though infested trees are seldom killed. Spruce gall midges/adelgids (*Adelges* spp. and *Pineus* spp.) cause characteristic pineapple shaped growths or galls to form at or near branch tips which can stunt or kill twigs. These species usually create unsightly features, but trees will grow out of the deformity. However, if other stressors (e.g., climate, secondary insect damage) combine then mortality can occur. Spruce web-spinning sawfly (*Cephalcia fascipennis*) primarily creates unsightly appearance and is more of a landscaping issue.

9.3. Primary Diseases

Eastern Dwarf Mistletoe (*Arceuthobium pusillum*)

Areas along the coastline, particularly along the Atlantic and Gulf of St. Lawrence with frequent coastal fog and cool humidity may experience significant stand-level mortality due to Eastern dwarf mistletoe. This parasitic plant causes the formation of clumps of swollen and brushy branches, or witches' brooms. This formation of brooms stimulates considerable resin flow that can extend over an area up to three meters in diameter. Witches' brooms caused by dwarf mistletoe can be distinguished from those associated with the rust pathogen *Melampsorella caryophyllacearum* by the fact that the needles are not shed when dwarf mistletoe is the causal organism, whereas they are shed with rust (CFS, 2024).

Root Rots (*Armillaria* spp.)

Currently there is not enough known about the potential damage caused by this fungus in Nova Scotia but in many other jurisdictions it has been extensive. Provincial annual aerial surveys of insect and disease outbreaks would have difficulty separating bark beetle needle browning from root rot caused discolouration. Much of what has been attributed to bark beetles may well have been due to armillaria. Armillaria fungal bodies were noted on white spruce during FEC data collection in the Shelburne area in 2010. Many of those stands have since died, though it is unknown if it was a combination of bark beetle, armillaria, and/or senescence.

9.4. Secondary Diseases

Damage caused by spruce needle blight/cast (*Lophodermium p*iceae), targets older needles. Spruce needle rust (*Basidiomycota Uredinales*) targets new growth. Damage by either fungi does not typically lead to tree mortality and is of more concern to landscaping and Christmas tree growers.

9.5. Others

Insects and diseases also influence other aspects of white spruce growth and survival. The seedling debarking weevil (*Hylobius congener*) feeds on the bark of young seedlings and usually causes mortality of planted and naturally regenerated seedings if more than 50% of the bark is removed. The weevil is attracted to harvested sites by the smell of decaying foliage which can extend for a minimum of two years following harvesting. There are also several cone and seed insects which can significantly reduce the quantity of viable seed produced during seed crop years. Spruce cone worm (*Dioryctria reniculelloides*) is the most common insect impacting cone crops and may sometimes during a severe infestation weaken the tree and increase susceptibility to attacks by other insects. According to Burns and Honkala (1990), mammals, birds, insects, and diseases reduce the number of cones and dispersed seeds. Squirrels can have a severe impact as well in some regions (e.g., Alaska). It is also reported there that insects can cause serious problems, including fir coneworm (*Dioryctria abietivorella*) and spruce seed moth (*Cydia strobilella*) that are reported as the most damaging.

10. Conclusions and Management Implications

A number of conclusions and management implications can be taken from the review, field observation, analysis, and synthesis done for this study. What is certainly clear is that white spruce is a nutrient demanding species. White spruce was exhibiting far more shade tolerance and longevity on richer ecosites, while pure stands of this nutrient-demanding species (e.g., old fields, plantations) often show much earlier decline and mortality. Where tree planting is used as a silviculture tool, caution should be taken when planted on poorer ecosites (e.g., AC6, AC7). Fertilization may be required on these ecosites for extended growth or upon a second-rotation plantation.

A consistent theme observed across decades of research and data collection in the FEC program, silviculture research program, and forest inventory PSPs, as well as the literature, is that white spruce can play very different successional roles in different ecosystems. It is well documented that white spruce is a shorter-lived species in old fields, plantations, the Highlands, and Coastal forests. This study further reinforces its role as an important, albeit smaller, LIT species component on richer ecosites in tolerant mixedwood and hardwood forests. Within the managed forest, the current silvicultural guidelines for Nova Scotia are heavily focused on uneven-aged management and restoring LIT species and in their silvics information defines white spruce as a LIT species in all FEC Forest Groups except the Old Field, Highland, Coastal Boreal, and Planted Forest Groups. The results of this study suggest that white spruce should only be considered a LIT species on tolerant mixedwood or tolerant hardwood ecosites. Within these two Forest Groups, this would include all VTs in the Tolerant Hardwood Forest Group and Mixedwood VTs except for MW9, MW10, MW11, and MW12. The same can be translated into old growth forests and old growth evaluation, where white spruce may be a LIT species on these ecosites but not in others. However, on-going research into white spruce regeneration success across all forest groups where it occurs will be critical in understanding its role as a LIT and non-LIT species, especially in the Spruce-Hemlock Forest Group. This should include research on seedbed requirements for white spruce regeneration and the potential impediments of the organic layer.

There are a number of important areas for future research revealed by this study. For example, the role, and potential future vulnerabilities, of old-field white spruce on the provincial wood supply will be important to understand given the changing land-use and agricultural patterns in Nova Scotia. Another valuable area of research would be updating the NSGNY model for plantations and naturally regenerated white spruce, incorporating the latest inventory PSPs and research PSPs. Updates to NSGNY for softwood plantations, including white spruce, was completed recently (Steenberg et al., 2023) but further research would be useful and the recent study did not include natural stands. Examination of the comparative yields of plantations versus naturally regenerated stands could be performed and validated with PSP data. Additionally, The examination of long-term white spruce plantation yields to determine whether dieback and slower growth compared to red spruce or black spruce is a result of nutrient deficiencies would be important, and could include collection of additional nutrient content data. Regarding plantations, there is a need for further research on the performance of improved white spruce breeding stock, such as realized growth gains across a nutrient gradient. In collaboration with the Atlantic Tree Improvement Council, existing tree improvement trials and datasets that could benefit from the assessment and incorporation of nutrient response traits into the breeding program. Further plantation research could also include establishing planting trials to determine optimum seedling and field handling techniques for early plantation performance and root development, including frozen stock and nutrient loading.

There are a several areas of potential future research for white spruce silvics and ecology that are specific to the Maritime Boreal Forest. On-going research and monitoring into white spruce silvics, in particular longevity, could be undertaken in these ecosystems where the species is presently not considered a LIT species in the SGEM. Moreover, there is the issue of white spruce regeneration in the Cape Breton Highland moose meadows and projecting their potential reforestation, including the role of white spruce in this restoration. This may also help verify the theories put forward about the pioneering role of white spruce. In addition, if white spruce does regenerate these sites, it would suggest that there may be a future regeneration problem when they die off in the next cycle, similar to old fields.

The impact of climate change on white spruce will be critical to understand and incorporate into management adaptations, especially as Nova Scotia continues to implement the Triad model and rely on white spruce as a key species in managed, high-production forests. In particular, impacts on the Maritime Boreal Forest should be assessed to determine if a reduction in balsam fir vigor will enhance white spruce abundance and growth or be a detriment. Lastly, the presence of white spruce on nearly all ecosites and in most VTs implies that this species may have an ecological role pertaining to other components of forest biodiversity that should be explored.

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