A silvicultural and economic comparison of clearcutting and partial cutting studies in northeastern North America

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Executive Summary

We reviewed and synthesized information sources that examine yield, regeneration, stand composition, costs, revenue and employment generated by clearcutting and partial cutting systems in the Acadian and other forest types in northeastern North America with the aim of informing an analysis of the potential impacts of reducing the prevalence of clearcutting in Nova Scotia.

Of the seventeen sources reviewed, four sources involved sugar maple dominated hardwood stands (Metzger and Tubbs 1978; Niese and Strong 1992; Robinson 1997; Stevenson 1996). Two other sources examined northern conifer dominated mixed-woods (Frank and Blum 1978; Sendak et al. 2003). One source examined each of the following forest types: black spruce-balsam-fir stands (Liu et al. 2007), hemlock dominated softwoods (Pannozzo and O'Brien 2001), red spruce dominated softwoods (Stewart et al. 2009), mixedwoods (Conservation Council of New Brunswick 2000), red spruce and balsam fir dominated mixed-woods (Pothier and Prévost 2008), beech dominated hardwoods (Leak and Wilson 1958) and red maple and beech dominated hardwoods (Leak 2003). Two sources examined forests that cover multiple forest types, including hardwoods, softwoods and mixed-woods (Erdle and Ward 2008; Pannozzo and O'Brien 2001), while another two sources did not describe in detail a particular forest type (Lansky 2002; Salonius 2007).

Each of the six sources that examine growth and yield indicate that over the long term (30-150 years), selection cutting, including single tree, group and strip cutting methods, generates growth and yield similar to or greater than the growth and yield obtained from clearcutting (Conservation Council of New Brunswick Inc. 2000; Erdle and Ward 2008; Niese and Strong 1992; Pannozzo and O'Brien 2001; Sendak et al. 2003; Stevenson et al. 1996). Yield and growth obtained from selection cutting was 2% to 74% higher than growth and yield obtained from clearcutting on similar sites.

Each of the three sources that compare regeneration after group and/or single tree selection cutting and clearcutting, including the only study conducted in Nova Scotia, indicate that selection cutting treatments (1) favour the regeneration of shade-tolerant species over shade-intolerant species, and (2) promote better regeneration of shade-tolerant species than clearcutting treatments (Frank and Blum 1978; Metzger and Tubbs 1971; Stewart et al. 2009). Two of the studies found total stocking after group and/or single tree selection cutting to be 50% and 10% higher than after clearcutting (Metzger and Tubbs 1971; Stewart et al. 2009) and the other study found total stocking to be equal after partial cutting and clearcutting (98-99%) (Frank and Blum 1978). Only one of the five studies examining regeneration found total stocking to be lower following single tree selection than following large scale clearcutting (Leak and Wilson 1958); this study was conducted in old-growth forest conditions, which are unlike most of Nova Scotia's forests (Mosseler et al. 2003).

The three sources that compare stand compositions 15 to 43 years after clearcutting and partial harvest treatments (group and/or single tree selection) show that selection cutting methods can

result in a greater prevalence of shade-tolerant tree species than clearcutting (Conservation Council of New Brunswick Inc. 2000; Leak and Wilson 1958; Sendak et al. 2003). One source found that the presence of red spruce and other preferred crop species had increased during the eight years following single tree and group selection harvests (Stewart et al. 2009). As well, one study (Leak 2003) showed that 1/5 ha (½ acre) patch cutting increases the abundance of yellow and white birch compared to the original stand.

The five information sources that examine employment indicate that employment per unit volume of wood harvested is approximately equal or higher under partial cutting systems than clearcutting, ranging between 3% less and 370% more employment per unit volume (Erdle and Ward 2008; Lansky 2002; Pannozzo and O'Brien 2001; Stevenson et al. 1996).

The four information sources that examine harvesting profitability indicate that partial cutting can be profitable (Liu et al. 2007; Niese and Strong 1992; Robinson 1997; Salonius 2007). One of these four sources indicates that single tree selection harvesting may yield 11.5% higher mean profits per cubic meter compared to the clearcut treatment ($58.40/m^3 and $52.39/m^3) (Liu et al. 2007). Another study indicates that relative to an uncut stand, the net present value (NPV) of single tree selection cut treatments ($496) are on average higher than the NPV of clearcutting ($-401) (Niese and Strong 1992). Stevenson et al. (1996) also indicate partial cutting can generate 100% or 190% more revenue per unit area than clearcutting, depending on the site being cut.

Based on the results of this information synthesis, we suggest that forestry in Nova Scotia on sites similar to those studied could be profitable and provide increased employment and yield if Nova Scotia were to transition away from clearcutting as the dominant harvest method. Increasing the use of partial harvesting methods, particularly single tree and group selection harvesting methods, could also increase the regeneration of shade tolerant, late-succession species that characterize mature Acadian forests.

We recognize that single tree and group selection harvesting may not be silviculturally appropriate for all sites in Nova Scotia, thus the results presented here should not be construed to apply equally to all sites. We suggest that these results apply to those sites that are silviculturally appropriate for partial cutting systems, as well as some sites with potential for restoration to silviculturally appropriate, and more valuable, Acadian Forest assemblages.

The possible increase in harvesting costs associated with a shift to partial cutting systems could be partially off-set by (1) redirecting a portion of current silviculture spending from practices associated with clearcutting to practices that promote partial cutting, and (2) adding new silviculture funding specifically for partial cutting treatments on private lands.

If our calculations and the assumptions of Erdle and Ward (2008) and the New Brunswick Federation of Woodlot Owners are correct, then reducing clearcutting across Nova Scotia by 50% while maintaining a provincial harvest level at Nova Scotia's 10-year average annual harvest volume would increase the overall cost of harvesting by \$4.06 to \$5.07 per m^3 on private lands and \$3.68 to \$4.60 per m^3 on public lands (14.4% to 18.1% and 12.8% to 16.0% of the current estimated average cost per volume of wood harvested, respectively) due to the lower harvesting efficiency of selection cutting methods. We estimate that \$1.87 and \$8.65 per m^3 are currently spent by the NS government on clearcutting-associated silviculture practices on private and public lands in Nova Scotia, respectively, which indicates an opportunity to offset potential increased costs of single tree and group selection harvesting through re-direction of silviculture spending, especially on Crown land. Other sources indicate that single tree selection harvesting could cost two to three times as much as clearcutting (Niese and Strong 2002, K. Thomas, personal communication, April 6th 2010), and as a result, re-directing silviculture spending may not be sufficient to cover the increased costs of this harvesting method.

Over the longer term (>25 years), the potential increased harvesting costs of single tree and group selection harvesting might also be offset by an increased timber yield per unit of land, and an increased per-unit-value of harvested wood, especially of hardwood, as the timber quality and species composition of stands improves.

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Introduction

Forestry in Nova Scotia is currently dominated by clearcutting. Over 90% of the forest area harvested in this province over the past ten years was clearcut (Canadian Council of Forest Ministers n.d.). In 2008, 97% of the $5.35 million spent on silviculture on Crown land was dedicated to paying for practices that support clearcutting (C. Weatherhead, personal communication, January 8th 2010). Similarly, 99% of the approximately $10 million spent on silviculture for private land (estimated based on silviculture credits claimed in 2008) was dedicated to paying for practices that support clearcutting such as site preparation and planting (Nova Scotia Department of Natural Resources 2009).

Twenty years ago Franklin (1989) advocated for a new approach to forestry that would acknowledge and respect ecosystem complexity and the importance of ecological goods and services provided by forests. Since that time, some forestry companies have shown interest in changing their practices. NewPage Corp and Abitibi-Bowater, for example, are exploring alternatives to clearcutting thanks in part to their involvement with Forest Stewardship Council (FSC) certification.

In 2008 the province of Nova Scotia began a 3-year analysis of its natural resources policies, with a goal of producing a new comprehensive Natural Resources Strategy. During the public engagement phase, Nova Scotians indicated that the current approach to natural resource management, including forest management, is not sustainable (Natural Resources Citizen Engagement Committee 2009). Many argued that clearcutting must be reduced or eliminated. Many also stated a desire for more uneven-aged forest management and an increasing number of rural jobs based on sound ecological principles.

The outcome of the public engagement phase corresponds with the results of polls conducted by Sanderson et al. (2000) indicating a large percentage of the public do not believe that forest management is currently sustainable as practiced on private company woodlands (52%), on privately-owned woodlands (43%), or on Crown lands (48%), while on average 30% indicated they did not know. Sixty-nine percent of the general public was in favour of selection and partial cutting as a forest management practice while 47% of respondents felt that clearcutting should be allowed only where suitable for the area being harvested and tree species. In addition, more than a third (38%) felt clearcutting should be banned. Another poll similarly found that 68% of Nova Scotians think there should be regulations that restrict where clearcutting can occur and another 27% think clearcutting should be banned in the province (Corporate Research Associates 2008).

This report compiles and summarizes the available literature on the silvicultural and economic outcomes of partial cutting and clearcutting systems in the Acadian Forest and other forests in northeastern North America with the aim of informing an analysis of the potential impacts of reducing the prevalence of clearcutting in Nova Scotia. Yield and growth, regeneration, stand composition, costs, profitability and employment were investigated. We also estimate the potential increase in harvesting costs associated with increased levels of group selection harvesting, and how increased harvest costs might be mitigated by changes to government silviculture spending. Lastly, relatively recent changes in forestry legislation and practices in Maine and impacts of those changes are briefly discussed.

Methods

Information Sources

We searched the available peer-reviewed scientific literature for studies comparing yield and growth, regeneration, stand composition, costs, profitability and/or employment resulting from various partial cutting and clearcutting methods in the Acadian and other forest types in northeastern North America. We also reviewed government studies, informal research reports, and conference proceedings, and solicited information from government and academic researchers, scientists and forestry professionals. Some of the studies we reviewed do not directly compare clearcutting and partial cutting. Some are combinations of trial results and estimates of potential outcomes, while others discuss only one type of harvesting practice.

Forest types

Four of the sources reviewed involved sugar maple dominated hardwood stands (Metzger and Tubbs 1978; Niese and Strong 1992; Robinson 1997; Stevenson 1996). Two other sources examined northern conifer dominated mixed-woods (Frank and Blum 1978; Sendak et al. 2003). One source examined each of the following forest types: black spruce-balsam-fir stands (Liu et al. 2007), hemlock dominated softwoods (Pannozzo and O'Brien 2001), red spruce dominated softwoods (Stewart et al. 2009), mixed-woods (Conservation Council of New Brunswick 2000), red spruce and balsam fir dominated mixed-woods (Pothier and Prévost 2008), beech dominated hardwoods (Leak and Wilson 1958) and red maple and beech dominated hardwoods (Leak 2003). Two sources examined forests that cover multiple forest types, including hardwoods, softwoods and mixed-woods (Erdle and Ward 2008; Pannozzo and O'Brien 2001), while another two sources did not describe in detail a particular forest type (Lansky 2002; Salonius 2007).

Results

Summary Tables

The following tables summarize basic information about the main information sources used in this report to examine differences in silvicultural and economic outcomes of clearcutting and various partial harvesting systems. The geographic location, species composition and time period considered in the yield, regeneration and stand composition information sources are provided (Table 1) as well as the yield and stocking values for those studies (Table 2) where applicable. Lastly, the geographic location, species composition and time period considered in the cost, profitability and employment information sources are summarized (Table 3).

Table 1: Summary of yield, regeneration and stand composition information sources

	Source	Geographic location	Species composition	Time period considered	Variable examined		
					Growth and/or yield	Regeneration	Stand composition
1	Pannozzo and O'Brien (2001)	Nova Scotia	Dominated by hemlock, red spruce and white pine, 3-5% each of white spruce, beech, white birch, red maple, red oak and white ash.	150 years	X		
2	Sendak et al. (2003)	Maine	Dominated by northern conifers; spruce (mostly red with some white), balsam fir, eastern hemlock, northern white-cedar, eastern white pine and some black spruce. Most common hardwoods: red maple, paper birch, grey birch and aspen.	40 years	X		X
3	Stevenson (1996)	New Brunswick	Primarily sugar maple, beech and yellow birch	45 years	X		
4	Conservation Council of New Brunswick (2000)	New Brunswick	Mixed wood dominated by red spruce, balsam fir, hemlock, poplar and red maple	43 years	X		X
5	Erdle and Ward (2008)	New Brunswick	Current species composition of New Brunswick's Crown forests (varies by site)	100 years	X		
6	Niese and Strong (1992)	Wisconsin	63% sugar maple, 4-9% each of yellow birch, white ash, red maple and basswood.	40 years	X		

7	Stewart et al. (2009)	Nova Scotia	Dominated by red spruce, moderate amounts of balsam fir and red maple, also present: yellow birch, white birch, sugar maple, white pine, black spruce, white spruce, beech and aspen.	8 years	X	X	X
8	Frank and Blum (1978)	Maine	Dominated by northern conifers; spruce (mostly red with some white), balsam fir, eastern hemlock, northern white-cedar, eastern white pine and some black spruce. Most common hardwoods; red maple, paper birch, grey birch and aspen.	19 years		X	
9	Metzger and Tubbs (1971)	Wisconsin	60% sugar maple, moderate amounts of yellow birch, hemlock, white ash and basswood, occasional rd maple, elm, paper birch, ironwood and black ash.	15 years		X	
10	Leak and Wilson (1958)	New Hampshire	60% beech; 20-25% yellow birch and sugar maple; minor components of red maple, paper birch, white ash, red spruce and hemlock.	15 years		X	X
11	Leak (2003)	New Hampshire	Dominated red maple and beech	47 years			X
12	Pothier and Prévost (2008)	Quebec	Dominated by red spruce and balsam fir, remainder of stand composed of eastern hemlock, eastern white cedar, red maple and yellow birch	10 years		X	

Table 2: Summary of yield and stocking values

	Source	Geographic location	Yield			Total stocking	
			Clearcutting	Selection harvest	Difference	Clearcutting	Partial harvest
1	Pannozzo and O'Brien (2001)	Nova Scotia	1.51m^3/ha/year	2.62m^3/ha/year	47% higher from single tree and group selection harvesting		
2	Sendak et al. (2003)	Maine	Between 3.2 and 3.8m^3/ha/year	Between 3.4 and 4.4m^3/ha/year	Between 6% and 16% higher from single tree and group selection harvesting		
3	Stevenson (1996)	New Brunswick	2.5m^3/ha/year	3.5 and 4.6m^3/ha/year	40% and 84% higher from single tree selection harvesting		
4	Conservation Council of New Brunswick (2000)	New Brunswick	2.1m^3/ha/year	3.4m^3/ha/year	62% higher from selection harvesting		
5	Erdle and Ward (2008)	New Brunswick	2.40m^3/ha/year	2.45m^3/ha/year	2% higher from strip and group selection harvesting		
6	Niese and Strong (1992)	Wisconsin	1.35m^3/ha/year	Between 1.6 and 2.2m^3/ha/year	Between 19% and 63% higher from single tree selection harvesting		
7	Stewart et al. (2009)	Nova Scotia				90%	100%
8	Frank and Blum (1978)	Maine				99%	98 and 99%
9	Metzger and Tubbs (1971)	Wisconsin				40%	90%
10	Leak and Wilson (1958)	New Hampshire				89%	87%(patch cuts), 67%(selection cuts)
11	Pothier and Prévost (2008)	Quebec				Red spruce: near 84% Balsam fir and deciduous species: near 100%	Red spruce: between 90 and 98% Balsam fir and deciduous species: near 100%

Note 1: The selection harvest yield from Pannozzo and O'Brien (2001) includes the standing volume remaining after 150 years

Note 2: Erdle and Ward (2008) do not strictly compare clearcutting and strip and group selection cutting but compare potential annual wood supply under a "status quo" management scheme (81% of harvested area is clearcut) and a natural disturbance based management scheme (45% of harvested area is clearcut)

Table 3: Summary of cost, profitability and employment information sources

	Source	Geographic location	Species composition	Time period considered
1	Robinson (1997)	Nova Scotia	Primarily sugar maple, white birch and white ash with a small proportion of yellow birch. One of the three stands studied also had significant components of suppressed white spruce and balsam fir.	First harvest only (i.e. one year time frame)
2	Lansky (2002)	Maine	Not specified	First harvest only (i.e. one year time frame)
3	Stevenson et al. (1996)	New Brunswick	Primarily sugar maple, beech and yellow birch	45 years
4	Salonius (2005)	New Brunswick	Not specified	80 years
5	Niese and Strong (1992)	Wisconsin	63% sugar maple and 4-9% each of basswood, yellow birch, white ash, red maple and hemlock	30 years
6	Liu et al. (2007)	Eastern Quebec	Composed mainly of black spruce and balsam fir	First harvest only (i.e. one year time frame)
7	Erdle and Ward (2008)	New Brunswick	Current species composition of New Brunswick's Crown forests (varies by site)	10 years (for the factors discussed in this report)

Yield and Growth

1. Pannozzo and O'Brien (2001) report that over a 150-year period (1840-1990) single tree and group selection harvesting generated an estimated 74% greater yield and growth than clearcutting from a 60-hectare woodlot on Windhorse Farm in southwest Nova Scotia. The property owner, Jim Drescher, estimated that more than 8 million board feet (more than 18,880m^3) had been harvested from the property over 150 years, and 2 million board feet (4,720m^3) of merchantable volume remained on the property at the end of those 150 years. Pannozzo and O'Brien estimate that clearcutting the same property every 50 years would generate 5.75 million board feet (13,570m^3), with no standing timber remaining after the final cut in 1990.

2. Sendak et al. (2003) published 40-year results of an experiment conducted in the Penobscot Experimental Forest in Maine that examine the impacts of various forest harvesting techniques on yield, growth, forest composition and other variables in stands of mixed northern conifers. Three single tree and group selection harvest variations were examined; however, no treatment was included in the experiment that would replicate conditions created by a clearcut in Nova Scotia. An unregulated harvest treatment, in which most or all of the commercially valuable trees were removed with no plan for regenerating a new stand, was included in the experiment, but sufficient residual trees were left in these stands to allow another harvest after 30 years. All commercial trees 16.5 cm dbh or larger in the first harvest and all commercial trees 11.4 cm dbh or larger in the second harvest were removed (Weaver et al. 2009). This harvest method is substantially different from clearcuts in Nova Scotia, which tend to remove all merchantable fiber.

Nonetheless, it is noteworthy that the 40-year yield from the single tree and group selection cuts was higher than the estimated initial standing volume of those blocks. The mean total yields of the three variations of single tree selection harvests were found to be 137.6, 136 and 176.3 m^3 per hectare, respectively, after the first 40 years of the study. The estimated initial mean wood volumes on the sites harvested using each of the three selection cut methods were 128.1, 135.9 and 151.9m^3 per hectare (J. Brissette, personal communication, December 14th 2009). These results indicate that selection cutting these stands would yield more volume than clearcutting these stands, assuming it would require more than 40 years for the clearcut stands to regain their initial volume of merchantable timber.

A similar long-term study was conducted in the Acadian Research Forest in New Brunswick from 1950 to 1987 (Swift 2007); yield data from those trials are not yet available (E. Swift, personal communication, January 6th 2010).

3. The New Brunswick Federation of Woodlot Owners evaluated and compared the potential employment, stumpage revenue and yield that could result from selection cutting (single tree and

group) and clearcutting over a 45-year period in western New Brunswick (Stevenson et al. 1996). Using data collected and observations made during the harvest of three woodlots, they estimated that the yield over 45 years from each of the two single tree and group selection cut blocks would be 30 cords per acre (156 m^3 per hectare) and 40 cords per acre (208 m^3 per hectare), respectively, while the yield from the clearcut block would be 22 cords per acre (114 m^3 per hectare) and decades would remain before the clearcut block could be harvested again. These estimates are based on the assumption that single tree and group selection harvests would take place every 15 years yielding similar volumes per area as the first selection harvests.

4. According to the Conservation Council of New Brunswick (2000), the Maritime College of Forest Technology, formerly known as the Maritime Forest Ranger School, established a long-term study in 1946 that aimed to compare the wood yields achieved from clearcutting, selection cutting and no cutting. The type of selection harvesting performed during this experiment is unclear in the documentation available. Over 43 years, the total volume of wood harvested from the clearcut area was 17 cords/acre (88.2 m^3 per hectare) while the total volume of wood harvested from the selection cut area, which was harvested 3 times during that period, was 28 cords/acre (145.3 m^3 per hectare). The volume of wood remaining on the selection cut area was also higher than on the clearcut and uncut areas. The study area's initial standing volume in 1946 was 17 cords per acre (88.2 m^3 per hectare); by 1989, the standing volume on the selection cut, clearcut and uncut areas in 1989 was 19, 17 and 24 cords per acre (98.6, 88.2 and 124.5 m^3 per hectare), respectively.

Overall, the total growth and yield, including both wood harvested and remaining standing wood volume, on selection cut, clearcut and uncut areas was 243.9, 176.4 and 124.5m^3 per hectare.

5. A forest-level analysis of forest harvesting systems was produced by Erdle and Ward (2008) for the New Brunswick Task Force on Forest Diversity and Wood Supply. The report estimates the potential wood supply, as well as numerous other variables, under various management scenarios for New Brunswick's Crown forests.

Over the short term (<25 years), a status quo approach to forest management (81% of harvesting by clearcutting) was predicted to generate 6.026 million m^3 per year, while a reduced clearcutting approach (45% of harvesting) that also aims to meet wood supply targets would generate 5.513 million m^3 per year. In contrast, the predicted wood supply over the longer term (>25 years) under the status quo scenario is 8.156 million m^3 per year, and under the reduced clearcutting scenario is 8.321 million m^3 per year. The difference over the long term is attributed to higher yields of cedar, white pine, white birch and red maple under the reduced clearcutting scenario. The volume of log-quality wood under the reduced clearcutting strategy was predicted to be 5.065 million m^3 per year for softwoods (16% higher than under the status quo scenario) and 558,000 m^3 per year for hardwoods (32% higher than under the status quo scenario). The higher annual log volume yields would result from favouring late–successional species, such as hardwoods and white pine, under the reduced clearcutting strategy. Strip and group selection cutting can also be used to promote log-quality trees. The total spruce-fir volume available for harvest each year was predicted to be similar under the short and long term of both scenarios due to a larger area being harvested under the reduced clearcutting scenario to compensate for lower intensity harvests.

Erdle and Ward (2008) performed a sensitivity analysis of harvest timing, log potential specification, the silviculture budget available, permanent retention in harvest areas, plantation yields and volume loss from windthrow. This last factor is of particular interest in the context of this report. In the body of their report, Erdle and Ward (2008) assumed no windthrow losses would occur as a result of partial harvesting. However, in their sensitivity analysis they examined the impact that a 15%, 30% or 45% loss of spruce/fir volume from areas where partial harvesting was applied would have. They found that if 45% of spruce/fir volume were to be lost under the reduced clearcutting management scenario, approximately 160,000 m^3 of wood volume per year would be lost to windthrow. If this worst case scenario of windthrow were to take place, the annual wood yield under the reduced clearcutting scenario would remain higher than the wood yield under the status quo scenario, though the magnitude of the difference would be reduced. Taking wind-throw into account, the predicted wood supply over the longer term is 8.156 million m^3 per year under the status quo scenario, and 8.161 million m^3 per year under the reduced clearcutting scenario.

6. Niese and Strong (1992) reported 40 years of data, including yield data, collected from a study in northern hardwoods in Wisconsin to evaluate the potential economic returns of various partial cutting treatments and clearcutting. They reported that the yields from selection cutting treatments were higher than the yield of the clearcutting treatment over the initial 30 years of the study. Clearcutting yielded 37.2 m^3 per hectare, while heavy, medium and light single tree selection cuts yielded 64.6, 64.4 and 47.9 m^3 per hectare, respectively, over that time period. The final basal area for the heavy, medium and light single tree selection cuts and clearcuts were 16.8, 20.0, 24.4 and 21.4 m^2 per hectare, respectively.

7. Nova Scotia Department of Natural Resources staff initiated a study in 2000 to examine the effects of different forest harvesting techniques, including single tree selection, group tree selection and clearcutting, on growth and yield, tree quality, regeneration, age class structure, blowdown and various ecological patterns in red spruce-dominated stands. Preliminary results from the 32 ha study area in Hants county are reported by Stewart et al. (2009).

The clearcut treatment was performed in 2000, and the single and group selection harvests were conducted in 2004. The mean net merchantable growth on the single tree selection, group selection, uncut and clearcut treatments were 25 m^3/ha, 29 m^3/ha, 14 m^3/ha and 0 m^3/ha, respectively, between 2000 and 2008 (Table 4); these growth rates do not account for growth that occurred on all sites on saplings and trees below merchantable size. As would be expected, the mean total volume harvested from the clearcut areas (285 m^3 per hectare) was higher than from either type of the partial cut areas (178 m^3 per hectare and 126 m^3 per hectare respectively). It is too early to determine the impact that harvesting methods have on the growth and yield, but given that this experiment in one of very few located in Nova Scotia, the future results of this study will provide valuable insight into the impacts of clearcutting and selection harvesting in this province.

Table 4: Harvested volumes, standing volume and net merchantable growth of trees >9.0 cm dbh before and after harvesting

Treatment	Mean Initial Volume 2000 m^3/ha	Mean Total Volume Harvested 2000 + 2004 m^3/ha	Mean Standing Inventory 2008 m^3/ha	Net Merchantable Growth between 2000 – 2008 m^3/ha
Uncut (control)	314	0	328	14
Single Tree Selection	299	178	146	25
Group Selection	265	126	168	29
Clearcut	285	285	0	0

Regeneration and Stand Composition

1. Stewart et al. (2009) reported changes in stand composition and differences in regeneration that resulted 8 years after various harvesting treatments were applied to a 32-hectare area in Hants County as part of a Nova Scotia Department of Natural Resources study.

The selection treatments increased the basal area proportion of red spruce as well as the overall basal area of all preferred crop species over the first 8 years of the study; favourable changes in species composition were greatest in the single-tree selection treatment. The proportion of balsam fir and red maple basal area decreased over the study period (Table 5).

Table 5: Basal area composition before and after treatments

Species	Single tree selection		Group selection	
	2000 (Initial conditions)	2008	2000 (Initial conditions)	2008
	% of basal area[1]	% of basal area	% of basal area	% of basal area
Red Spruce	65	84	68	70
Preferred crop species[2]	75	94	75	80
Balsam Fir	3.9	2.6	3.2	2.4
Red Maple	19.9	2.6	19.2	15.7

[1]All figures are mean values for the two blocks of each treatment

[2]Preferred crop species include red spruce, yellow birch, white pine and sugar maple

In 2006, all of the selection-cut blocks had 100% total stocking (established seedling, 6-130cm height) with similarly high average stocking percentages of 84%, 76% and 76% for red spruce, balsam fir and red maple, respectively, across all blocks. Average stocking of yellow birch was 40%, (most yellow birch seedlings were concentrated in extraction trails). Total stocking was slightly lower in the clearcut blocks, averaging 90%. Stocking in clearcut blocks averaged 64% for red spruce, 40% for balsam fir, 71% for red maple and 18% for yellow birch. Sapling stocking was highest in the two group selection blocks at 46% while the sapling stocking was 25% and 38% in each of the two single tree selection blocks and 25% and 29% the two clearcut blocks.

2. Frank and Blum (1978) reported early regeneration results from a long-term study in Maine's Penobscot Experimental Forest. Nineteen years after the initial harvest, the average stem density of the three single tree and group selection harvest treatments ranged from 7,890 to 19,080 stems per acre (19,450 to 47,150 stems per hectare) while the stem density on the unregulated harvest was 12,470 stems per acre (30,810 stems per hectare) at that time. The stem density and stocking percentage of spruce and hemlock were higher under selection cutting (spruce: 128% more stems per acre, 33% higher stocking; hemlock: 119% more stems per acre, 24% higher stocking) while red maple and "other species" stem densities were higher under the unregulated harvest treatment (red maple: 94% more stems per acre, 18% higher stocking; other species: 156% more stems per acre, 21% higher stocking) (Table 3). Total stocking and balsam fir stocking were high and virtually the same across all treatments at 98% or 99% (Table 6).

Table 6: Status of regeneration 19 years after initial harvests

Species	Selection: 5-year interval		Selection: 10-year interval		Selection: 20-year interval		Commercial clearcut (unregulated harvest)	
	Stocking (%)	Number of stems per acre	Stocking (%)	Number of stems per acre	Stocking (%)	Number of stems per acre	Stocking (%)	Number of stems per acre
Spruce	77	1160	88	2500	89	730	52	640
Balsam fir	94	3990	98	9290	94	2730	98	6700
Hemlock	93	5030	72	5510	91	3830	61	2190
Red maple	82	1070	58	1030	59	300	84	1550
Paper birch	28	490	23	290	12	100	28	360
Other species*	38	780	49	460	21	200	57	1030
All species	99	12520	99	19080	98	7890	99	12470

*Includes grey birch, aspen, white pine and cedar

3. Sendak et al. (2003) report that forty years after the establishment of that same Penobscot Experiment, the basal area of spruce (mostly red spruce with some white spruce) within the three single tree and group selection-cut treatments increased by 9%, 15% and 15% compared to initial composition, while the fir component remained the same or decreased (increase of 3% and decreases of 14% and 1%) under those treatments. The hardwood component on the selection blocks increased by 1% and 6% in two of the blocks and decreased by 11% in the third; the most common hardwoods on the sites were shade-intolerant or moderately shade-tolerant species, including paper birch, grey birch, aspen and red maple. In contrast, the spruce component of the total basal area of the unregulated harvest site (commercial clearcut) decreased by 10%, the fir component stayed the roughly the same (1% increase) and hardwoods, mostly shade-intolerant or moderately shade-tolerant, increased by 30%.

As previously noted, the unregulated harvesting used during this experiment left more residual live trees than is generally the case in Nova Scotia. Shifts to shade-intolerant species could be expected to be more dramatic with clearcutting that leaves fewer residual trees.

4. The results from a 43-year-long experiment conducted by the Maritime College of Forest Technology that aimed to compare the wood yields achieved from clearcutting, selection cutting and no cutting indicate that selection cutting increases the prevalence of shade-tolerant species more than clearcutting does (Conservation Council of New Brunswick 2000). Initially, all of the treatment areas were dominated by red spruce, balsam fir, hemlock, poplar and red maple. At the end of the study period, the selection cut was dominated by red spruce with smaller amounts of hemlock and red maple, while the clearcut area was dominated by poplar with an understory of red spruce and balsam fir.

5. Metzger and Tubbs (1971) examined the regeneration present 15 years after a variety of cutting methods were applied to sugar maple dominated northern hardwood stands in Wisconsin's Argonne Experimental Forest. Overall they found the stem density and stocking to be higher and regeneration was more evenly distributed in the blocks harvested using single tree selection cutting than in blocks where clearcutting prescriptions were applied. The three single tree-selection methods tested resulted in an average stocking of desirable species of approximately 90%; the complete block, patch and strip clearcut treatments, which removed all trees greater that 1 inch in diameter, resulted in approximately 43% stocking.

The single tree selection cuts also had higher stem densities of regeneration, ranging from approximately 89,000 to 106,000 stems (greater than 6 inches tall and less than 2 inches dbh) per hectare (36,000 to 43,000 stems per acre), while the strip and block clearcut treatments had on average 44,000 and 22,000 stems per hectare (18,000 and 9,000 stems per acre), respectively. The strip and block clearcut stands had much higher stem densities (121,000 and 57,000 stems per hectare, respectively) one year after they were harvested, but regeneration density declined dramatically over the next 14 years as shrubs, grasses and sedges came to dominate much of the blocks. Moisture stress is suggested as a factor in the decline of stems on the clearcut blocks.

The patch clearcut method, which might more accurately be called a partial cut since harvested patches ranged from 0.024 to 0.081 hectares (0.06 to 0.2 acres) in size, also had low stocking (43%), but a relatively high seedling density of 74,000 seedlings per hectare (30,000 seedlings per acre) indicating that regeneration was unevenly distributed and formed clumps across the site. However, the small quadrat size (1.0 m^2 or 1/4 milacre) used to determine stocking and regeneration may have exaggerated the extent to which regeneration was poorly distributed after patch, strip and block clearcutting.

The number of moderately shade-tolerant and shade-intolerant stems per acre were similar across harvesting treatments, but the proportion of these stems per acre was larger on the clearcut sites (44% after strip clearcuts and 67% after block clearcutting) than in the single tree selection cuts (ranging from 17% to 19%), in which sugar maple stems were more dominant.

While the stands studied were largely dominated by sugar maple, making them different from many of Nova Scotia's forests, this study suggests that single tree selection cutting methods result in superior regeneration of shade-tolerant species, and equivalent regeneration of trees with intermediate tolerance, compared with the larger opening harvest treatment.

6. Leak and Wilson (1958) indicate that adequate natural regeneration occurs in old-growth northern hardwoods (Bartlett Experimental Forest, New Hampshire) independent of the harvesting methods used; they add, however, that this generalization does not apply to younger, second-growth

hardwoods. Their analysis of regeneration data 10 to 15 years after the application of clearcutting indicates that total stocking was higher in the clearcut stands than in the two partial cutting treatments.

The stocking in clearcuts was 89% while the stocking in patch and single tree selection cuts was 87% and 67% respectively. They also found that the single tree selection method favoured shade tolerant species (83% of stocking was shade tolerant species), the patch method favoured intermediate and tolerant species in proportions of approximately 1:2 (55% and 40% of stocking was shade-tolerant and intermediate species, respectively), and the clearcut contained intolerant, intermediate and tolerant species in proportions of 2:1:2 (39%, 19% and 42% of the stocking was tolerant, intermediate and shade intolerant, respectively). It should be noted that the authors stressed that these results are applicable only to old-growth hardwood stands, of which there are few in Nova Scotia (Mosseler et al. 2003). Also, the clearcutting prescription used in this experiment is different from clearcuts in Nova Scotia and might more accurately be named a diameter-limit cut. Hardwoods were cut to a minimum dbh of 1.6 inches (4cm) and softwoods were cut to a minimum of 4.6 inches (12cm).

7. In another study based in the Bartlett Experimental Forest, Leak (2003) presented data from a patch harvest study in second growth beech and red maple dominated hardwood forest. Results from 47 years after the initial patch cuts, averaging 0.2 hectares (0.5 acres) in size, indicate that paper and yellow birch and red maple were the dominant regeneration in the centres of patches (Table 8).

Table 8: Percentage basal area by species in initial stand (1954) and in current (2002) patch centres

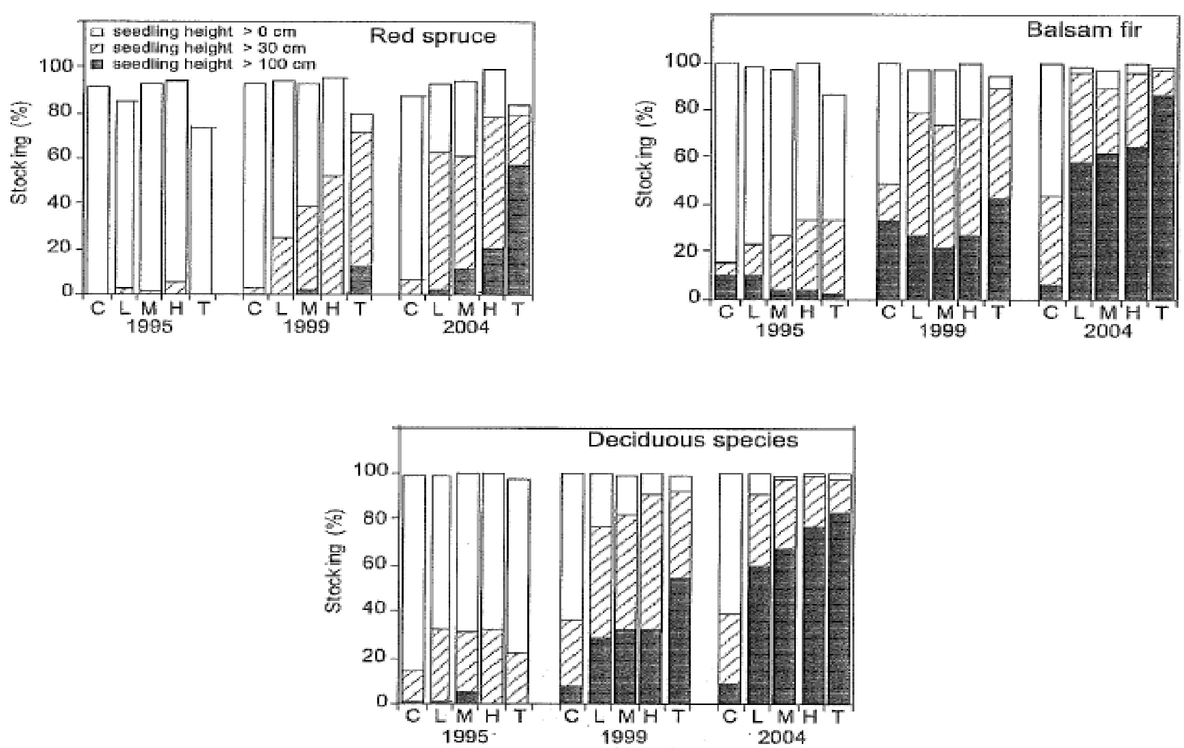
	Initial stand	Current patch centres	
Species	15.2 cm dbh +	12.7 cm dbh +	20.3 cm dbh +
Beech	23.7	26.4	9.1
Yellow birch	11.7	17	18.9
Sugar maple	3.1	2.7	3
Red maple	28.4	15.4	26.7
Paper birch	8.5	34.5	39.3
White ash	2.1	1.7	3
Red spruce	7.1	1.5	~
Hemlock	13.8	0.8	~
Others	1.6	~	~

8. Pothier and Prévost (2008) compared regeneration following shelterwood and clearcut prescriptions in red spruce and balsam fir dominated stands in eastern Quebec. The size of their experimental units may make the results of their clearcutting treatment more representative of patch cutting methods. At a size of 50m by 50m (0.25 ha, 0.6 acre), their clearcuts were much smaller than typical clearcuts in Nova Scotia.

The red spruce and balsam fir stocking in the shelterwood cuts ranged from approximately 85% to 93% and 97% to 100%, respectively, in the year following the initial harvest, while the stocking in the clearcuts was approximately 70% and 85% respectively. Red spruce and balsam fir were the two main species that made up advanced regeneration on the test sites and the differences between treatments is attributed to extensive machinery damage to advanced regeneration in the skidding trails of the clearcut treatment sites. Ten years after the initial treatment, overall stocking of balsam fir was nearly 100% across all treatments while red spruce stocking had increased to approximately 80% in the clearcut treatment. When regeneration of all height classes was considered, the differences in red spruce stocking among the different cutting intensities were insignificant. Deciduous species stocking across all treatments one year after the harvest and 10 years after harvest was nearly 100%.

Seedling growth of all species over 9 years following the harvest was found to be more rapid in the clearcut units than in the shelterwood units (Figure 1). These differences in seedling growth may be due to differences in light availability resulting from the various treatments.

Figure 1: Changes in mean regeneration stocking over time for red spruce, balsam fir and deciduous species after application of five cutting treatments: untreated control (C); low (L), moderate (M) and heavy (H) partial cuttings; and total clear-cutting (T)



Costs, Profitability and Employment

1. A 1.8 hectare harvesting trial conducted by Robinson (1997) in Wreck Cove, Nova Scotia, investigated whether the initial cut of a single tree selection cutting system would be viable despite a prevalence of poor quality stems resulting in part from past high grading and extensive clearcutting. Perhaps contrary to popular thought, the study found that the revenue generated from the initial cut was sufficient to cover the cost of the operation and generated a profit of $\$3.22/m^3$ (1997 dollars). The margin of error for harvest costs (plus or minus \$90) and log sales (plus or minus \$156.80) collectively amounted to a margin of error of \$246.80 for the operation as a whole. Assuming the worst case scenario of the highest harvest costs and lowest log sales revenue within these ranges, the profit per volume would be reduced to $\$2.36/m^3$.

Assuming a "job" in forestry consists of 40 hours of work per week during 52 weeks of employment and using the employment and harvest volumes from Robinson (1997), we calculated the employment per volume of this trial to be 0.55 jobs per $1000m^3$ of wood harvested. At first glance, the 10-year average employment per volume in forestry and forestry support (not including milling) in Nova Scotia, which would currently largely result from clearcutting due to the prevalence of that harvesting practice in this province, is a slightly higher value of 0.60 jobs per $1000m^3$ of wood harvested. However, this latter value includes both part time and full time jobs making it unfair to compare the two values.

2. In an analysis of forestry in Maine, Lansky (2002) estimated the cost of low-impact harvesting (which emphasizes selection harvesting and includes a comprehensive management plan), and the cost of clearcutting using a standard accounting formula and data from logging contactors. While the cost of low-impact harvesting was \$7 more per cord (approximately \$14.80 more per m^3) than the cost of clearcutting, Lansky points out that labour made up 60% of the cost of the low-impact harvest while labour accounted for only 25% of the cost of clearcutting. This indicates that while selection harvesting methods may be more expensive than conventional clearcutting methods, they can create more employment per volume harvested.

3. Pannozzo and O'Brien (2001) document examples of existing and profitable forestry operations that utilize partial cutting methods for most or all of their harvests, including Algonquin Park in Ontario, a 7,633 km^2 provincial park managed for multiple uses, including forestry. The Algonquin Park operation generates more forestry and milling jobs per volume of wood harvested than currently generated in Nova Scotia's forest industry, which is based on clearcutting as the primary harvesting method. Pannozzo and O'Brien (2001) estimate that Algonquin Park generates 4.1 forestry and milling jobs per 1000 m^3 of wood harvested, while the 10-year Nova Scotian average of part-time and full-time jobs generated per volume of wood harvested is 1.7 jobs per 1000 m^3 based on data from Statistics Canada (n.d.).

4. A report produced by the New Brunswick Federation of Woodlot Owners (Stevenson et al. 1996) projected, evaluated and compared the potential employment, stumpage revenue and yield that could result from selection cutting (single tree and group) and clearcutting over a 45-year period in western New Brunswick. It was estimated that managing the studied woodlots using partial cutting would result in approximately twice the amount of employment (148 hours per hectare and 217 hours per hectare for each of the selection cut blocks respectively) compared to clearcutting (86 hours per hectare) over a 45-year period. Overall, the employment per unit of wood volume for the two selection cuts was estimated to be 0.95 hours per m^3 (0.46 jobs per 1000 m^3) and 1.04 hours per m^3 (0.5 jobs per 1000 m^3), while the clearcut was estimated to generate 0.75 hours per m^3 (0.36 jobs per 1000 m^3).

Lastly, the stumpage revenue from partial cutting was projected to be higher over the 45-year time period (approximately $2,700 per hectare and $4,000 per hectare for the selection cut stands and $1,360 per hectare for the clearcut stand (1996 dollars)) due to the greater volume and quality of wood cut from those areas in addition to a management incentive from a local mill. All of these estimates are based on the assumption that single tree and group selection harvests would take place every 15 years, yielding slightly increased proportions of higher quality products after the first harvest. Note, harvesting costs were not discussed in this report.

5. Also in New Brunswick, Salonius (2007) estimated the profitability of strip cutting with permanent retention strips as an alternative to clearcutting. His calculations estimated the net present value of a 1.8 ha forest stand under such a silvicultural system, in 2000 dollars, to be $13,534.43 ($7,519 per ha) over 80 years. Net present value (NPV) is defined as the sum of all future cash flows, including both revenues and expenses, generated by a project, with each cash flow discounted back to the present. The positive NPV of Salonius' proposed strip cutting method indicates that it is an acceptable investment option. Salonius (2007) did not, however, provide a comparison of the NPV of his strip cutting method to the NPV of a clearcut on a similar hypothetical site.

5. In a study in north-eastern Wisconsin, Niese and Strong (1992) evaluated the potential economic returns of several partial cutting treatments and clearcutting using 30 years of data from northern hardwood stands. They found the NPV of clearcut stands to be $401 per hectare (1990 dollars) less than the un-cut control blocks, while the stands harvested using single tree selection cutting had NPVs ranging from $298 per hectare to $718 per hectare more than the uncut control blocks. This indicates that for the stands studied, single tree selection cutting is a better investment option than clearcutting, despite the costs of single tree selection treatments (including management costs) being almost twice the cost of the clearcutting treatments ($296 per hectare versus $159 per hectare, in 1990 dollars). The researchers attribute their results to the lack of harvestable trees remaining after the clearcutting treatment, and the low yield of clearcutting (40.5 m^2 per ha) compared with uneven-aged harvesting (47.9 to 64.65 m^2 per ha) over the 30 years of the study.

6. In Eastern Quebec, a study by Liu et al. (2007) compared the immediate (first year of harvest) financial return of partial cutting strategies and clearcutting in black spruce-balsam fir stands with irregular structures and good potential for partial cutting methods. The study considered the revenues generated from the wood harvested under each treatment as well as the costs of harvesting[1], transportation (not including the cost of road construction) and lumber processing during that initial harvest. While the clearcut blocks were found to have the highest profit per hectare because the of the higher volume of wood harvested, the two single tree selection cut treatments yielded 7.6 and 19.9% higher mean profits per cubic meter (\$58.40/m^3 and \$52.39/m^3) compared to the clearcut treatment (\$48.70/m^3).

The lower profit per cubic meter of wood in the clearcut harvest can be attributed to (1) a 3.5% lower value per wood volume of the clearcut wood (Liu et al. 2007), and (2) a higher percentage of small-diameter stems, which led to higher harvesting and lumber processing costs (J.C. Ruel, personal communication, December 10th 2009).

This difference in profit per cubic meter indicates that selection cutting would likely be more profitable than clearcutting over the long term under conditions similar to those of this experiment, and would continue to be more profitable into the future so long as the yield from a site harvested using selection cutting would be equal to, or greater than, the yield from clearcutting over the period of interest.

7. In addition to the yield predictions described above, Erdle and Ward (2008) estimated (1) the employment level in the forest industry, (2) the royalties obtained by the Crown, (3) the total value of harvested wood (called value of shipments) and (4) the cost of wood production and harvesting, among other factors, under various management scenarios for New Brunswick's Crown forests. While the results of their study indicate that although continuing current management strategies (including 81% clearcutting) appears to be more favourable over the short term (years 1 to 25) due to higher yields during that initial period, decreasing clearcutting to 45% of the total forest area harvested, while also meeting timber supply objectives, could result in more employment, more royalty revenue and a higher value of harvested wood over the longer term (>25 years).

The authors predicted that continuing current management strategies would result in 7,600 jobs per year in the forestry industry and \$61 million in royalties in the first ten years of the implementation, while a scenario that decreases clearcutting while also meeting timber supply objectives would support 6,700 jobs per year and generate \$55 million in royalties. The total value of wood harvested is predicted

[1] Note, Liu et al. (2007) appear to have determined harvesting costs based on the volume of wood and dbh of trees harvested from each stand. They do not mention factors such as lower harvesting efficiencies that could result in higher costs for selection harvesting than clearcutting.

to be $1.44 billion per year for the first scenario over the same period and $1.19 billion per year under the reduced clearcutting scenario, based on the volume of different wood types harvested and the current unit selling prices of pulp, lumber and veneer. These differences are largely due to a higher total volume of wood harvested over the short term under the current management scenario (6,026,000 m^3/year versus 5,513,000 m^3/year). Wood product value, royalties and employment rates are largely found to be proportional to the total volume of wood harvested in the Erdle report. For example, the scenario with high rates of clearcutting is projected to generate 1.26 jobs per 1000 m^3 of wood volume while the reduced clearcutting scenario would generate 1.22 jobs per 1000 m^3. These figures include jobs resulting from logging, silviculture and manufacturing of pulp and solid wood products.

Predicting the net value and resulting employment over a short period of time is sensible considering the difficulties and uncertainties inherent in predicting wood prices over the long term. However, as the authors pointed out, these short-term positive results may not continue into the longer term. The authors' analysis indicated that annual wood yields would be higher under the reduced clearcutting scenario during years 26 – 100 of their modeling exercise (8,321,000 m^3/year versus 8,156,000 m^3/year). This change in yield indicates that the net value of wood harvested, royalties and employment rates in New Brunswick would likely be higher over the longer term under a reduced clearcutting scenario.

Lastly, Erdle and Ward (2008) predicted that combined silviculture and harvesting costs would be $43.3/$m^3$ and $45.7/$m^3$ under the status quo and reduced clearcutting scenarios respectively.

Estimated Harvesting Cost Increase for Nova Scotia

The impact of a decreased level of clearcutting in Nova Scotia on the harvesting cost can be evaluated using estimates of various harvesting costs provided by Erdle and Ward (2008) and the New Brunswick Federation of Woodlot Owners along with data from the National Forestry Database (Canadian Council of Forest Ministers n.d.) and the annual Registry of Buyers report by the Nova Scotia Department of Natural Resources (2009).

Erdle and Ward (2008) estimated the cost of clearcutting and uneven-aged harvesting (using strip and group selection) to be $28 per m^3 and $36 per m^3, respectively. The New Brunswick Federation of Woodlot Owners estimates the cost of single tree selection harvesting, which was the predominant partial harvesting method used in the studies we reviewed, to be $8 to $10 more per cubic meter of wood harvested than the cost of clearcutting ($38 to $40 total per cubic meter) based on informal conversations with members of their organisation (K. Hardie, personal communication, April 9th 2010). Using these estimates, if the area harvested using clearcutting were reduced by 50%, while maintaining a ten-year mean (1998-2007) volume of wood harvested, we estimate that the overall cost of harvesting would increase by $3.95 to $4.94 per cubic meter (14% to 17.5% of the current average cost per volume of wood harvested), assuming the cost estimates by Erdle and Ward (2008) and the New Brunswick Federation of Woodlot Owners are accurate and equally applicable in NS. If those same changes were applied to private and Crown land separately, as opposed to over the province as a whole, the increase in harvest costs would be $4.06 to $5.07 per cubic meter on private lands and $3.68 to $4.60 per cubic meter on public lands.

Interestingly, the amount of money spent on clearcutting-associated silviculture practices[2] in Nova Scotia's forests in 2008 divided by the volume of wood typically harvested annually in the province[3] amounts to $2.59 per cubic meter of wood harvested. This figure can be broken down into $1.87 per cubic meter of wood harvested on private lands (estimated based on the silvicultural credits claimed in 2008) and $8.65 per cubic meter of wood harvested on public lands (based on actual spending data provided to the authors by C. Weatherhead on January 8th 2010).

Thus, based on estimates by Erdle and Ward (2008) and the New Brunswick Federation of Woodlot Owners, transitioning to partial cutting methods could incur higher harvesting costs on private lands that would only be partially offset by reinvestment of clearcutting-based silviculture spending into partial-cutting-based silviculture. New silviculture funding specifically for various types of partial cutting may be necessary to encourage private land owners to adopt partial cutting practices. On Crown lands, in contrast, it appears that the higher costs of strip and group selection harvesting could be more than offset by shifting silviculture funding currently spent on clearcutting-associated silviculture practices towards partial harvest treatments.

It is important to add that it is also possible that if single tree selection harvesting, the predominant partial harvesting method used in the studies we reviewed, were to be used more widely across the province the increase in harvesting costs could be higher than the estimates above. One forester in New Brunswick estimated that single tree selection costs approximately 2 to 3 times more than clearcutting (K. Thomas, personal communication, April 6th 2010), which corresponds with harvesting and management costs reported by Niese and Strong (2002). This higher cost of single tree selection harvesting would not be completely offset by reinvestment of silviculture funding; however, the potential increased profitability of single tree selection, as shown by Niese and Strong (2002), as well as the higher quality of wood that could be obtained using this method, could provide sufficient motivation for land owners and forest managers to adopt these practices.

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[2] Clearcutting-associated silviculture practices include practices that fall under categories 1 through 6 of Nova Scotia's silviculture credit system, as well as seed tree cuts and site preparation.
[3] Harvest volume data are not yet available for 2008; the mean volume of roundwood harvested between 1998 and 2007 was used to calculate the cost per volume values presented here.

Additional Case Study of Interest

The results of implementing Maine's *Forest Practices Act* (Maine Forest Service 2009) are worth considering for Nova Scotia. This *Act* contributed to a decrease in clearcutting in Maine, where 95% of forested land is privately owned, from 51% of the total forest area harvested in the early 1980s to less than 3% of the area harvested in 2008. The *Act* requires that all clearcuts over 20 acres (8 hectares) be justified according to prescribed criteria[4], and the justification must be confirmed by a professional forester or wildlife biologist.

The decrease in clearcutting in Maine must be taken with a grain of salt, given the flexible definitions of clearcutting and partial harvesting. According to M. Lansky (personal correspondence, December 1st 2009), a harvest legally defined as 'partial' may actually result in very few residual standing trees. Lansky draws attention to 'shelterwood overstory' cuts that remove all of the mature wood on a site, and to partial cuts that leave as little as 6.9 m^2/ha of basal area. According to Lanksy, these harvests would have been called "commercial clearcuts" before the *Forest Practices Act.* As well, while clearcutting has decreased in Maine, the annual harvest level has gradually increased since 1980 and the use of shelterwood harvesting has also increased (K. Laustsen, personal communication, December 10th 2009). This has resulted in lower intensity but more widespread forest harvesting, with a possible concern of increased forest fragmentation (A.A. Whitman, personal communication, December 1st 2009).

Data detailing employment in Maine's forestry sector before 2000 are difficult to obtain; however, long-term staff with the Maine Forest Service indicate that employment in the forestry industry declined substantially from 1990 to 2000, though factors other than the *Forest Practices Act* were likely responsible for this decline (C. Holland, personal communication, December 16th 2009; D. Mansius, personal communication, December 1st 2009). Craig Holland, Northern-East District Manager for Labor Market Information with Maine's Department of Labor, suggests that the decline in employment is due to the high costs of worker compensation in the early 1990s, compounded with developments in forest harvesting machinery that resulted in a shift to more mechanized harvesting systems.

[4] (1) Removal of poor quality, intolerant, understocked, short lived or mature overstories where the retention of the residual overstory trees is not justified for further increase in value, as a source of seed, or for protection of the new stand; (2) Ecologically appropriate improvement or creation of wildlife habitat, with accompanying prescription and justification from a certified wildlife professional; (3) Removal of timber stands that, if partially harvested according to accepted silvicultural practice, are at high risk for windthrow due to factors such as soils, rooting depth, crown ratio or stem quality; or (4) Harvesting of an existing plantation or other forest stands established by or previously treated with precommercial silvicultural activities.

Discussion

Results from each of the six sources that examine growth and yield indicate that over the long term (30-150 years), single tree and group selection cutting generates growth and yield similar to or greater than the growth and yield obtained from clearcutting (Conservation Council of New Brunswick Inc. 2000; Erdle and Ward 2008; Niese and Strong 1992; Pannozzo and O'Brien 2001; Sendak et al. 2003; Stevenson et al. 1996). Yield and growth obtained from single tree and group selection cutting were 2% to 74% higher than growth and yield obtained from clearcutting on similar sites.

Each of the three sources that compare regeneration after selection cutting and clearcutting, including the only study conducted in Nova Scotia, indicate that single tree and group selection cutting treatments (1) favour the regeneration of shade-tolerant species over shade-intolerant species, and (2) promote better regeneration of shade-tolerant species than clearcutting treatments (Frank and Blum 1978; Metzger and Tubbs 1971; Stewart et al. 2009). Two of the studies found total stocking to be 50% and 10% higher after partial cutting (Metzger and Tubbs 1971; Stewart et al. 2009) and the other found total stocking to be equal after partial cutting and clearcutting (98-99%) (Frank and Blum 1978). Only one of the five studies examining regeneration found total stocking to be lower following partial cuts than following large scale clearcutting (Leak and Wilson 1958); this study involves old-growth conditions, which are unlike most of Nova Scotia's forests (Mosseler et al. 2003).

The three sources that compare stand compositions 15 to 43 years after clearcutting and partial harvest treatments show that partial cutting can result in a greater prevalence of shade-tolerant tree species than clearcutting (Conservation Council of New Brunswick Inc. 2000; Leak and Wilson 1958; Sendak et al. 2003). One source found that the presence of red spruce and other preferred crop species had increased during the eight years following single tree and group selection harvests (Stewart et al. 2009). As well, one study (Leak 2003) showed that 1/5 ha (½ acre) patch cutting increases the abundance of yellow and white birch compared to the original stand.

The five information sources that examine employment indicate that employment per unit volume of wood harvested is approximately equal or higher under partial cutting systems than clearcutting, ranging between 3% less and 370% more employment per unit volume (Erdle and Ward 2008; Lansky 2002; Pannozzo and O'Brien 2001; Stevenson et al. 1996).

The four information sources that examine harvesting profitability indicate that partial cutting can be profitable (Liu et al. 2007; Niese and Strong 1992; Robinson 1997; Salonius 2007). One of these four sources indicates that single tree selection harvesting may yield 11.5% higher mean profits per cubic meter compared to the clearcut treatment ($58.40/m^3 and $52.39/m^3) (Liu et al. 2007). Another study indicates that relative to an uncut stand, the net present value (NPV) of single tree selection cut treatments ($496/ha) are on average higher than the NPV of clearcutting (-$401/ha) (Niese and Strong 1992). Stevenson et al. (1996) also indicate partial cutting can generate 100% or 190% more revenue per unit area than clearcutting, depending on the site being cut.

Estimates we made indicate the possible increase in harvesting costs (according to Erdle and Ward 2008 and the New Brunswick Federation of Woodlot Owners) associated with a shift to partial cutting systems could be off-set by (1) shifting a portion of current silviculture spending from practices associated with clearcutting to practices that promote partial cutting, and (2) adding new silviculture funding specifically for partial cutting on private lands; however, this may not be sufficient to fully offset the increased costs associated with single tree selection harvesting. Over the longer term (>25 years), potential increased harvesting costs might also be offset by an increased per-unit-value of harvested wood, especially of hardwood, as the proportion of more valuable species (intermediate and shade tolerant) and the overall quality of stands increase due to quality-based selection management, and an increased timber yield per unit of land.

Although the above results are largely supportive of partial cutting practices, it should be noted that few of the sources we reviewed included statistical and/or sensitivity analyses. Of the few statistical analyses performed, Pothier and Prévost (2008) found that regeneration 9 years after small scale clearcuts is not significantly different from regeneration after partial cutting. Two other reports (Erdle and Ward 2008; Robinson 1997) demonstrated that the predicted trends (profitability and greater yield of partial harvesting in the long term) remain unchanged when the worst-case scenarios of uncertainties are taken into account, though the magnitude of differences resulting from differing harvesting methods is diminished.

Furthermore, there are risks associated with the single tree and group selection methods that have not been discussed in this report. Under certain circumstances, partial harvesting can increase the susceptibility of remaining trees to windthrow. Selection cutting, if done improperly, can also result in low quality stands as a result of high grading and soil and tree damage during harvesting. Both of these risks could impact the variables discussed above including profitability and yield.

Conclusion

This report reviews and synthesizes information sources that can be used to compare the yield and growth, regeneration, stand composition, harvesting costs, profitability and employment that result from clearcutting and partial-cutting methods.

Based on the results of this information synthesis, we suggest that forestry in Nova Scotia on sites similar to those studied could be profitable and provide increased employment, wood value and wood yield if Nova Scotia were to transition away from clearcutting as the dominant harvest method. Increasing the use of partial harvesting methods, particularly selection harvesting, could also increase the regeneration of higher value, shade-tolerant, late-succession species that characterize mature Acadian forests.

Reducing clearcutting by 50% in Nova Scotia, while maintaining a 10-year mean annual harvest level, may result in increased harvest costs on some sites.   Increased harvesting costs could be fully or partially off-set by shifting current silviculture spending away from treatments that support clearcutting toward treatments supporting partial harvest techniques, and through the increased profitability, yield per hectare, and stand quality associated with partial harvesting over the long term on appropriate sites.

We recognize that selection and other partial harvesting may not be silviculturally appropriate for all sites in Nova Scotia, thus the results presented here should not be construed to apply equally to all sites. We suggest that these results apply to those sites that are silviculturally appropriate for partial-cutting systems, as well as some sites with a long-term potential for restoration to late-successional Acadian Forest species assemblages.

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Appendix 1

Table A1 below indicates whether the studies included in this report involve actual, on the ground data or whether they involve hypothetical estimates. It also indicates whether the source itself compares clearcutting and partial cutting. Lastly, it indicates whether the source has reported a statistical and/or sensitivity analysis.

Table A1: Additional study qualities

Study	Estimate?	Comparison?	Statistical or sensitivity analysis
Pannozzo and O'Brien (2001)	Yes- clearcut yields by source	Yes- selection data is real, clearcut data is estimate	No
Sendak et al. (2003)	Yes- clearcut yield estimated by me	Yes- selection and unregulated data is real, I used initial stand volumes to estimate clearcut data	Yes- but for selection and unregulated not clearcutting
Stevenson et al. (1996)	Yes- initial values from clearcutting and future values from all treatments by source	Yes	No
Conservation Council of New Brunswick (2000)	No- real data	Yes	No
Erdle and Ward (2008)	Yes	Yes- but not of clearcutting and partial harvesting, instead looked at strategies that involve both methods in different quantities	Yes- looks at a couple of factors in a sensitivity analysis, windthrow is of particular interest
Niese and Strong (1992)	No- real data	Yes	No
Stewart et al. (2009)	No- real data	Yes	No
Frank and Blum (1978)	No- real data	Yes- selection harvest and unregulated harvesting	No
Metzger and Tubbs (1971)	No- real data	Yes- multiple partial cut and clearcut methods	No
Leak and Wilson (1958)	No- real data	Yes	No
Pothier and Prévost (2008)	No- real data	Yes- shelterwood and clearcutting	Yes
Robinson (1997)	No- real data	No	Yes-sensitivity
Lansky (2002)	Yes	Yes- clearcutting and partial cutting	No
Salonius (2005)	Yes	No	No
Liu et al. (2007)	Yes- actual harvest took place, product recovery and costs were simulated	Yes	Yes- but just looked at differences in stand value before and after treatment, not for differences in profit ratios