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An Evaluation of a Forest Resource—A Case Study from Nova Scotia

F. B. Goldsmith†

Department of Biology, Dalhousie University, Halifax, Nova Scotia, Canada

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An extensive tract of forest, occupying over 4 million hectares and 84% of the province of Nova Scotia, is examined in terms of its past structure and species composition, its history of logging and burning and its current harvesting practices. The resource base is believed to have deteriorated in terms of height, girth, species compostion, increase of fire barrens, nutrient depletion, shortages of sawtimber and softwood for pulp. Current proposals to "complete-tree" harvest on short rotations are likely to further deplete the already nutrient-deficient soils of some parts of the province. The forest industry has had to shift from species to species as the resource has adjusted to increasingly intensive exploitation and now, in spite of legislation and grant-aid, there is a real risk that options for the future are being reduced.

Keywords: resource evaluation, forest history, whole-tree harvesting, nutrient cycling, Nova Scotia.

1. Introduction

As O'Riordan (1971) and others have indicated, there is a wide variety of ways in which the efficiency and environmental costs of resource management can be evaluated. It is possible to assess social, economic, political and ecological costs and benefits of various actions. In another paper, the author tried to evaluate ecological resources in the countryside for conservation purposes (Goldsmith, 1975). Here, an extensive forest resource (Nova Scotia) is assessed in terms of its past and future potential to produce valuable fibre. The evaluation involves a historical survey of the past use of the area, the present structure and species composition of the resource, and the nutrient status of the soils which will support the next crop. It is not possible to predict the relative value of different fibre products in the future, but I assume that we should aim to produce

† Now at Department of Botany and Microbiology, University College London, Gower Street, London WC1E 6BT, England.

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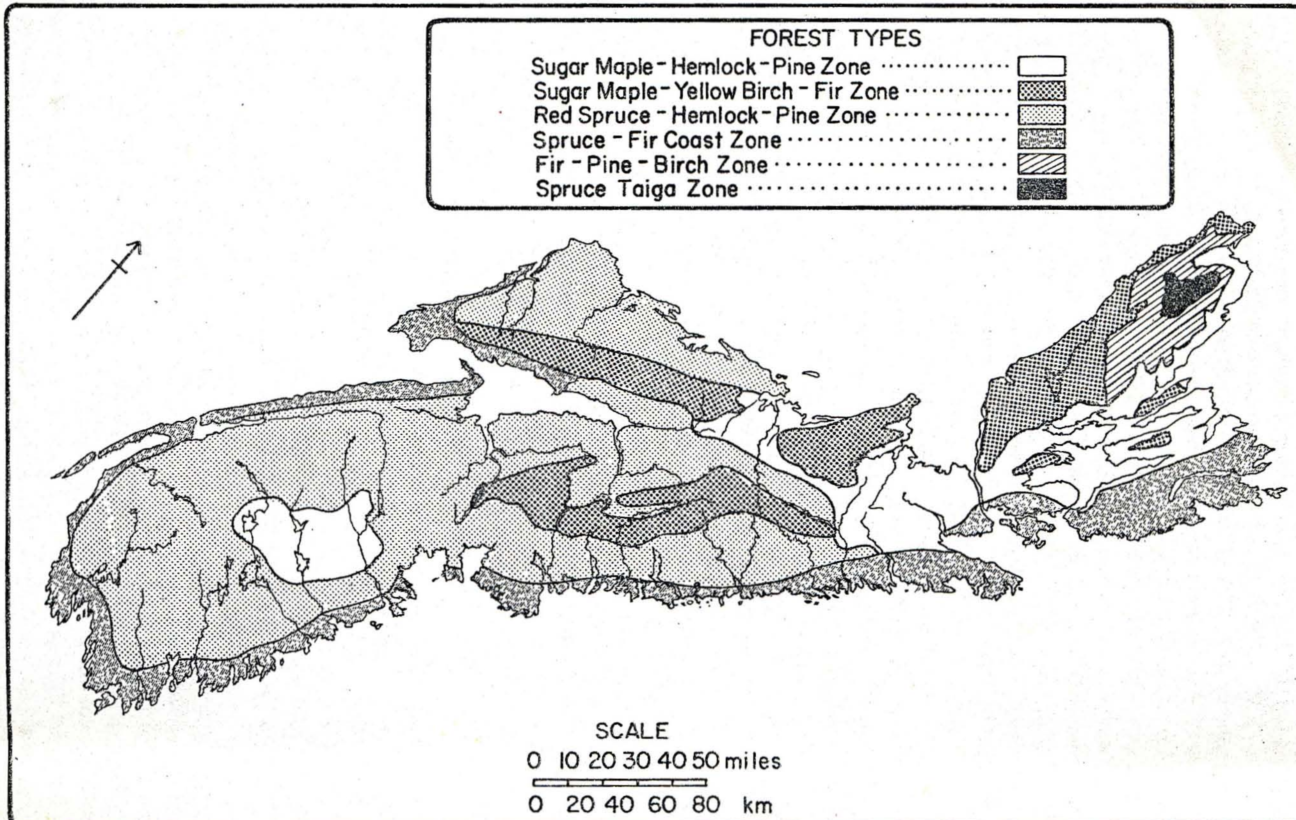

Figure 1. Forest zones of Nova Scotia (based on Department of Development, 1975).

the highest value product and ensure as wide a range of options as possible for any area in the future.

Nova Scotia's forests are part of Canada's Acadian Forest Region and represent a mixture of northern coniferous species and some hardwood components (Rowe, 1972; Loucks, 1962). The main forest types are shown in Figure 1 based on the Forestry Atlas published by the Department of Development (1975). They cover 84% of the land surface of the province (10·8 million acres, 4·37 m ha) and, since early colonial days, have been a major source of material for construction and of income from world trade. Unlike most of Canada, where an average of over 90% of land is owned by the Crown, 75% of land in Nova Scotia is privately owned. This extensive private ownership makes management and harvesting particularly challenging, especially because half of the privately owned land is in lots of less than 1000 acres (405 ha) and the average lot size is only 250 acres (101 ha). Furthermore, Crown land tends to be located on poorer soil and has more difficult access than privately owned land.

The tradition in Nova Scotia has been either to "highgrade" the forest for lumber (sawlogs) or, increasingly since the 1890s, to clearcut for pulp and paper production. Regeneration has been good and most people have not worried about the growing of trees (silviculture). A few people, however, have suggested that these forest resources have been exploited rather than conserved, just as Nova Scotian gypsum is quarried, exported and cannot be regenerated. The essential difference between a mineral and the forest is that the former is non-renewable and the latter, if properly managed, is renewable. For minerals, we can only consider the rate of removal and the possibility of recycling. For the forest, appropriate management can result in programs of sustained levels of cropping over long periods of time.

There are major constraints on tree growth in the province. The first of these is the climate: the growing season (defined as days over 5°C) is short and varies from about five months in Cape Breton to seven months near Yarmouth, in the south-west. The second is the soil; granite and other igneous rocks are predominant, covering over 3500 square miles (9065 km^2) of the province. They weather extremely slowly to give an acid and nutrient-poor soil. Glacial till helps to alleviate this constraint on plant growth, but is often also nutrient-poor. The interaction of factors such as high levels of precipitation, coniferous leaf litter, shallow soils and locally impeded drainage provides an inhospitable environment for plants. Left to itself, nature makes the best of these meagre gifts, but repeated cutting, burning and local erosion have probably reduced the stature of the forest and possibly changed the species composition. It is highly probable that colonising hardwood species such as red maple, white birch, trembling aspen, alder and balsam poplar have increased in abundance, whilst more valuable trees such as yellow birch, white pine, hemlock and red spruce have decreased.

If the range of options open to future human generations in terms of the variety, quantity and quality of products available from the forest are to be maintained, it will be necessary to think carefully about that old-established yet elusive concept of sustained yield. The yield of this renewable resource can be increased by improved management such as spacing (thinning) or fertilizer application. To-day, we realise that it is also important to consider non-timber forest benefits such as landscape value, recreational potential, wildlife and the protection of water catchments, but it is not easy to measure these benefits, let alone compare them in common units of measurement.

Ecologists know remarkably little about the effects of highgrading and clearcutting (as opposed to selection felling) on regeneration, soil structure or nutrient status. A little is known about the cycling of nitrogen, phosphorus and potassium in relatively stable forests, but much less about the effects of clearcutting on the natural processes of nitrification and nitrogen fixation (see for example Likens *et al.*, 1977).

Demand predictions for forest products are notoriously unreliable, but a continuous increase in demand is probable. Nova Scotia only supplies about 2% of Canada's lumber exports, but lumber is one of the three major Nova Scotian products. Various estimates of the value of these products are available, but a value of $170 million does not appear improbable. In terms of employment, it is again difficult to calculate how many people work in forestry and related industries, partly because many people are involved in, for example, both agriculture and forestry, and partly because it becomes difficult to decide which secondary and tertiary industries to include. However, a substantial number of people in the province depend on the forests for their livelihood. Any improvement in forest management inevitably results in increased employment and the multiplier effects of secondary and tertiary employment probably result in at least a doubling of the numbers employed.

The province has a wide range of rock, soil and climatic types for its relatively small area, and these, in combination with coastal and freshwater features, provide a wealth of ecological interest. The International Biological Programme identified 69 special ecological sites within the province, and these sites are shown in various official documents, for example the Nova Scotia Resource Development Atlas. At present, there is no legislation to protect these sites and no policy for acquiring those that are privately owned. [For a more detailed discussion, see Weetman (1972) and Stanley (1977).]

Most resource economists agree that the critical world commodities are food, fibre and fuel. Fuel or energy is usually interpreted as oil supplies, natural gas, nuclear power, wind or tidal power, but the traditional use of wood as fuel may well resurrect itself in Nova Scotia. The province is probably over-exploiting its softwoods (Nova Scotia Forest Products Association, 1970) yet cropping less than the allowable cut of its hardwoods. Areas of mixed hardwoods and softwoods are often neglected, but, under a policy of integrated harvesting, the best timber could go for sawlogs, the remaining softwoods for pulp, and the remaining hardwoods chipped, fed into generating stations and converted into electricity. What, however, are the implications for wildlife, recreation and amenity as well as the site nutrient capital?

There are many trends in forest management and extraction which are determined by the demands of the market and considerations of cost. In Nova Scotia, the number of sawmills rose from 27 in the year 1767 to 1401 in the year 1861, and then steadily declined as the pulp industry increased in importance. The number of sawmills dropped to 350 in 1973, and, to-day, there is a trend of increasing concentration of activity and specialization. Eight per cent of the mills produce 60% of the lumber and boxwood, whilst 77·6% of total wood fibre is processed in only five pulp mills.

In the process of extraction, clearcutting has largely replaced selective logging and highgrading, but the environmental implications of this change are hardly understood. The Hubbard Brook Ecosystem Study in New Hampshire (Likens *et al.*, 1977) has shown that erosion from clearcut areas increased from 2·5 to 38 metric tons per square kilometre per annum and that there was also a significant increase in the loss of dissolved substances. This loss only occurs every 40 years or so, but can rainfall be relied on to make good these losses in ecosystems as deficient in nutrients as those of Nova Scotia?

Another important consideration is whether forestry, as one important form of land use, should be considered in isolation from others. In some parts of Nova Scotia (e.g. Annapolis, Shubenacadie, Stewiacke and Upper Musquodoboit Valleys), there is competition for land between forestry and agriculture. There is competition between cottage development, recreation, wildlife conservation and forestry along the eastern and southern shores and many lakesides. How are these broader issues of resource allocation and management to be resolved?

It is thus apparent that a series of questions arise about integrated resource management in Nova Scotia which all have an ecological basis. Various disciplines are important, especially geology, pedology, economics, sociology and law, but the common meeting-ground should be the ecological characteristics of the resource itself. The vegetation is an obvious expression of the environmental constraints, past management and future potential of the forest resource.

2. History of exploitation

Natural and semi-natural types of vegetation are dynamic and changes occur as a result of climatic fluctuations and population phenomena within the species themselves. Seral stages in forests can last for several hundred years and natural outbreaks of pests and diseases can also occur over quite long time periods. Hence, in examining Nova Scotia's forests, we must bear in mind that human impacts have been relatively recent and of lesser significance than, say, glacial effects, which had such marked effects on geomorphology and soils as well as on the vegetation and fauna.

Today, there is considerable spatial variability due to differences in geology, soil and climate, and such variability certainly existed prior to human interference so that there has never been a uniform forest type in Nova Scotia. This diversity has been exploited by man, who selects those species useful to himself and removes them. This exploitation was practised by the Micmac Indians and has been pursued through history to the present day. The critical question is whether the intensive cropping of successive species such as white pine and red spruce has had a serious impact on the forest of today, i.e. on its species composition, yield, soil structure and nutrient status. To answer this question we can start by looking at the historical evidence for change (Figure 2).

Prior to about 1600, the impact of the Indian population was probably in balance with the forest ecosystem and we could say that the forest could support that number of people over an indefinite period of time. The yield that man was taking was, therefore, sustainable. It is interesting to examine the early reports of European settlers who first came to Nova Scotia.

Lescarbot (1606), a Frenchman based for a short time at Annapolis Royal, comments on the richness of game but says rather little about the forest itself. He observed that organic fertilizer increased the yield of the vegetable plots, which suggests that even then Nova Scotian soils were fairly nutrient-deficient. Denys (1672) writes in much greater detail about forest structure and species composition and describes species with which we are familiar today. One report attributed to him in 1688 suggests that all the masting (white pine) is not good in the province which suggests that some areas in the original forest were poorly stocked or had small trees (see Fergusson, 1954).

As early as 1728, the British government had to introduce measures to protect the better white pine trees as masting for the navy. Individual trees over 24 inches (61 cm) diameter were marked with the traditional broad arrow and this practice continued until 1760. By 1762, there are reports of "no more masting" in the province.

In 1773, Morris, a Surveyor-General of Nova Scotia, describes black birch (probably yellow birch) "in bigness about 9 ft or 12 ft girth" (2·74 or 3·66 m) on Cape Breton (see Fergusson, 1954). Other people have described birch forests on mainland Nova Scotia that one could ride a horse underneath in living memory, and it is possible that

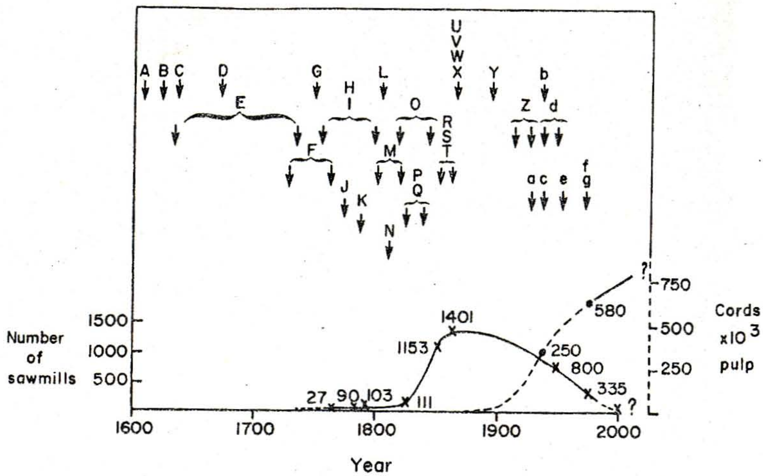

Figure 2. History of forest exploitation in Nova Scotia. Summary of forest history is as follows:

A	1605	First logs cut at Port Royal.
B	1621	Province received its Royal Charter.
C	1632	Razilly, French Governor in Denys' time, organized the export of lumber.
D	1672	Denys' book first published.
E	1629–1731	Period of turmoil (wars and strife).
F	1728–1760	Broad arrow policy to protect large white pines.
G	1749	Halifax founded.
H	1759–1800	Peak of land grants.
I	1762	"No more masting" reported (Morris quoted by Fergusson, 1954).
J	1773	Morris reports large yellow birches on Cape Breton, better than oak or mahogany.
K	1784	Lumber imported from U.S. to Shelburne.
L	1801–1802	Titus Smith Jr. conducts his survey.
M	1800–1818	Shiploads of fir to England increase from 565–28 059 per annum.
N	1808	Supplies of Baltic timber cut off by Napoleonic Wars.
O	1815–1840	40 000 immigrants arrive from Europe.
P	1824–1838	1600 ships built.
Q	1829	Colonial restrictions lifted, shipbuilding started in earnest in N.S.
R	1845	First steam mill erected by Davison Lumber Company.
S	1850	Cedars and hackmatack for ship's knees depleted (Fergusson, 1954).
T	1853–1861	1491 ships built.
U	1864	"No square timber left" (Lower, 1973).
V	1867	Confederation of Canadian provinces.
W	1869	Hardy's book published.
X	1870	"Pine all gone" (Lower, 1973).
Y	1875–1890	Pulp industry started.
Z	1914–1918	First World War—increased demand.
a	1925	$1\frac{1}{2}$ million worth of pulp exported.
b	1935	First forest inventory by Department of Lands and Forests.
c	1935	$6 million worth of pulp and newsprint exported.
d	1939–1945	Second World War—increased demand.
e	1951	$18 million worth of pulp and newsprint exported.
f	1970	75% of forest in private land. Forestry exports are 26% of Nova Scotia exports.
g	1971	About 77% of the fibre production is exported as pulp from five mills.

The key sources used here are Fergusson (1954) for lumbering in the province and Donaldson (1961 for the pulp industry. Hardy (1869), Lescarbot (1606), Diereville (1708), Smith (1802) and Haliburton (1864) provide interesting contemporary insights whilst Bentley and Smith (1957), Lower (1938, 1973), Archibald (1972) and Johnson (1978) review various historical events.

many of these areas are currently covered by balsam fir, scrubby red maple and white birch such as appear so common today.

In 1784, there is reference to timber being imported from the United States, which indicates that there was little timber suitable for house construction at Shelburne and Halifax at that time. In the same year, John Wentworth, Governor of Nova Scotia and Surveyor-General of Woods of all British territories in America, commented that nearer the centre of the province (Grand Lake, Shubenacadie) there were still pines 2 ft–2 ft 6 inches (61–76 cm) diameter and clear of branches for 50 ft (15 m) (see Fergusson, 1954).

By then, the province had entered a period of rapidly increasing demands for timber and the number of sawmills was steadily increasing from 27 in 1767 to 90 in 1785 (Figure 2). This was the period of massive European settlement, with land grants reaching their peak between 1759 and 1800, shiploads of "fir" being exported to England, increasing from 565 in the year 1800 to 28 059 in the year 1818. Europe was cut off from its Baltic supplies of timber in 1808 by the Napoleonic Wars and turned to North America for its supplies. Shipbuilding within the province entered a boom phase with 600 vessels built between 1824 and 1830, 1000 ships built between 1831 and 1838, and 1491 built between 1853 and 1861. Between the years 1815 and 1840, 40 000 new immigrants arrived (Archibald, 1972) and presumably many more timber homes were built and large quantities of wood used for furniture and fuel. By 1860, Nova Scotia's forests must have looked very different from one hundred years previously. This history suggests that the accounts written before this period provide us with a pre-exploitation description, and that the accounts after 1860 give a kind of post-blitz impression. By 1861, the number of sawmills reached 1401, a number never to be equalled again in the province's history.

During this very interesting period, there is a detailed and comprehensive account by Titus Smith, Jr. (1802) which describes three journeys by land across the province. His report repeatedly mentions barrens, indicating that they were probably fairly extensive then.

More recently, Captain Hardy, writing in 1869, describes the forest in considerable detail. He reports that "the burnt barrens extend for many miles, and are most dreary in their appearance and painfully tedious to travel through". He must rank as the greatest champion of conservation in the province and it is worth quoting Hardy directly:

> "In the hands of which class of men does this colony now find itself? And I fear the unhesitating answer of the impartial stranger and visitor would be, that in all regarding the preservation of our living natural resources, we were in the hands of the destroyers. The course of destruction so ably depicted by the author quoted, is being presented throughout the length and breadth of Nova Scotia, and the settlers of this province, blind to their own interests, careless of their children, and utterly regardless of restraint imposed by the laws of the country, worse than useless because not carried out, are bringing about the final depopulation of our large wild areas of land and water."

After Hardy's time, matters probably became worse because the pulp industry started about 1875, and, by the year 1900, about 45 000 cords of pulp per annum were being processed. At the same time, shortages of wood for constructional purposes and changing market demands resulted in a rapid expansion of the pulp industry and a parallel decline in sawmilling.

In 1912, the condition of the forest resource was such that Fernow (1912) made the following statement:

> "It is now largely in poor condition, and is being annually further deteriorated

> by abuse and injudicious use, because those owning it are mostly not concerned in its future, or do not realise its potentialities. To arrest deterioration and to begin restoration is the present duty of those who have the continued prosperity of the Province at heart."

Then followed the rapid expansion of the pulp industry and the demands of the First World War.

Between 1937 and 1940, a series of annual reports of the Nova Scotia Department of Lands and Forests continue to criticise overcutting practices. For example, in 1937 . . .

> ". . . the cut of lumber and allied products last year was far in excess of growth during the same period, it is natural to ask if any steps may be taken to ensure the future of the lumbering industry."

and in 1940 . . .

> ". . . lumbering has continued because changed conditions and methods have permitted inferior tree species and smaller sizes to be marketed."

and, in 1958, Hawboldt and Bulmer (1958), conclude their discussion with the statement . . .

> ". . . higher standards of forest management than presently practised must be adopted."

At the present time, it is probable that softwood species are being overexploited whilst less than the allowable cut of hardwoods is being taken. It is probable that species change and nutrient depletion are the most serious problems and these are discussed later. It is hoped that a detailed knowledge of past exploitation will help formulate a more cautious policy for the future.

3. Concept of sustained yield

There are two main types of resources. Stock resources, such as minerals, are essentially non-renewable and the main consideration for them is the rate of exploitation and the possibility of recycling. Flow resources, however, are renewable and all biological resources, being capable of growth and self-replenishment, fall into this category if properly managed. Forests are good examples of flow resources, but various levels of yield are possible, depending on the intensity of exploitation. A sustained yield can be maintained indefinitely or can be increased by modifying the limiting ecological factor. A sustained yield of timber can be obtained from the forests of Nova Scotia without any special management. The yield can, however, be increased by, for example, adding fertilizer, and, as long as the supplementation is provided, the level of cropping can be increased. There are other products of the forest, which are usually called non-timber benefits, for example game, and their yield can be increased by modifying the intensity or pattern of timber production. The yield of one often interferes with the yield of the other, so that the optimization of the various categories of yield can be a difficult and often controversial problem.

Forest resource managers have to calculate an allowable cut for each year. This calculation is usually based on repeated inventories of the stock of timber and should ensure that only the growth or interest is removed and that the stock or capital is not depleted. In Nova Scotia, there have only been two detailed inventories, published in 1958 and 1965–1971, and each has been based on a different type of survey so that direct comparisons are difficult.

Each inventory is essentially a static account of the volume of timber available in seven divisions, whereas the resource is dynamic and growing whilst being irregularly and disproportionately cut. The divisions contain a wide range of land capability types (usually from Canada Land Inventory index 3–7), whereas the cutting is concentrated on the better forest land. There is a danger here that, whilst overall figures for estimated growth and volume cut may balance, the better land may be over-exploited. It is preferable to use area-based regulation and to encourage the more efficient harvesting and utilization of fibre.

To ensure the continuance of a healthy forest, it is also necessary to ensure that the age class and girth structure of the forest does not deteriorate. It is important to have young trees to replace those that die or are cut, but their proportion should not be greater than necessary. It is also vital to ensure that the species composition of a forest does not deteriorate. Many inventories focus on volume of timber and overlook the fact that high value timber is being replaced by that of less desirable species.

In Nova Scotia, white pine was the major species used by the industry up to about 1860, when it was replaced by red spruce and this species has now decreased in volume so that the forest industry is focusing on balsam fir, white spruce and black spruce as well as red spruce.

4. Evidence of deterioration

Forest resources, if improperly managed, deteriorate over time-spans of decades or centuries and, consequently, changes are sometimes unnoticed by the general public. Many people who are conscious of such changes play them down because they are employed by large commercial forest operations or because the federal and provincial agencies responsible for forests discourage their staff from making independent comments. Change has to be determined by comparison with a base-line inventory, but the first inventory was published in 1958, after 350 years of intensive cropping. The evidence of deterioration that is available for Nova Scotia comes from seven sources.

4.1. HEIGHT AND GIRTH

There are references in the literature to the height of white pines, height to canopy [clear of branches for 50 ft (15 m)] and girth of yellow birch [9–12 ft (2·7–3·7 m) in 1773]. All sources suggest that the dimensions of both hardwood and softwood trees in Nova Scotia have decreased since pre-colonial times.

4.2. SPECIES COMPOSITION

There is strong evidence that repeated cutting of softwoods from mixed stands encourages the regeneration of hardwoods by sprouting or coppicing. Unfortunately, these are usually "colonising" hardwood species such as red maple, white birch, alder and trembling aspen which have a low commercial value. Strang (1971) reports that "following burning or commercial felling or both, the natural succession is first to a hardwood phase in much of the Scotian peninsula" (see also Taylor, 1959).

Between 1958 and the latest inventory (1965–1971), there is evidence of further changes in species abundance. If we focus on hardwoods, valuable species such as sugar maple, yellow birch and white ash have decreased (see Table 1) whereas low value species such as red maple and white birch have increased dramatically.

TABLE 1. Changes in volume of a valuable species (white ash) and a colonising species (red maple) in various counties of Nova Scotia

County	1958†	1965/1971*	
	White Ash		
Halifax	24·2	1·0	Gross vol (m cu ft)
Hants.	17·0	2·4	
Cumberland	36·5	2·2	
Colchester	23·5	2·0	
Guysborough	6·7	0·5	
Pictou	9·4	2·7	
	*Red Maple**		
Cumberland and Colchester	+69·5%		Change in gross vol per division between 1955 and 1967/1971
Annapolis and Kings	+58·6%		
Halifax and Hants.	+45·0%		
Queens and Lunenburg	+34·2%		

Eastern Ecological Research (1976), with reference to dry sites in the Kejimikujik National Park, indicates the course of succession after cutting and fire. The climax is either white pine, red spruce or shade-tolerant hardwoods, e.g. sugar maple, yellow birch and beech. Fire produces "sucker (root) growth of intolerant hardwoods", e.g. red maple, red oak and white birch. These are shrubby in form, multiple-stemmed and of low commercial value. Lees (1978) has reviewed the literature on hardwood silviculture [see also Prager and Goldsmith (1977) for information about stump sprout formation by red maple]. Only slowly does the more valuable yellow birch, sugar maple, white pine and red spruce invade. Severe fire produces a useless barren of broom crowberry (*Corena conradii*), bracken (*Pteridium aquilinum*) or huckleberry (*Gaylussacia baccata*). Other descriptions of succession after cutting are provided by Taylor (1959) and after burning by Martin (1956).

4.3. INCREASE OF FIRE BARRENS

Perkins (1961) describes extensive fires in the period 1790–1796 and fire barrens were undoubtedly present in 1801 when Titus Smith, Jr. conducted his survey. There is evidence of forest fire in prehistoric pollen records for the forest (Ogden, 1969). However, there is also evidence that the extent of these barrens has increased dramatically in recent historical time. Canadian Forestry Service Reports (Strang, 1971) suggest that just the southern half of Nova Scotia has seen the generation of 500 000 additional acres of unproductive land (202 340 ha) in the last few decades (see also Strang, 1970, 1972; and Wall, 1975, 1977).

* From Inventory Section, DLF (1967). 1958 inventory data for hardwoods should be reduced by 20% to make it comparable to the 1965/1971 series.

† From Hawboldt and Bulmer (1958).

4.4. DEPLETION OF NUTRIENTS

The construction of nutrient budgets is time-consuming and difficult, but it may nevertheless be considered surprising that no budgets have been prepared for any of the major nutrients in Nova Scotia. The province has one of the longest histories of logging in North America and some of the most nutrient-deficient soils. If any region is likely to experience a serious nutrient depletion problem, it is Nova Scotia. Of the four key nutrients, calcium, nitrogen, phosphorus and potassium, it is probable that phosphorus is the most important. Accordingly, an attempt was made to prepare a desk-based budget for this element. There are some data for soils and for trees of different species in nearby Maine (Young and Carpenter, 1967). The incoming precipitation and weathering (which is assumed to be extremely small) are assumed to provide $0{\cdot}6\ \mathrm{kg}^P/\mathrm{ha/year}$, and run-off and drainage to lose $0{\cdot}4\ \mathrm{kg}^P/\mathrm{ha/year}$. Fire may have resulted in the loss of about 0·1 kg/ha/year over the centuries and the balance has probably accumulated in the biome. The first felling of trees, say about 1800, would result in the loss of about two-thirds of the accumulation over the age of the trees (perhaps 150 years). If the rate of accumulation by spruce is $0{\cdot}6\ \mathrm{kg}^P/\mathrm{ha/year}$, as in Germany and Russia, then the loss would be $0{\cdot}5 \times 150 \times 0{\cdot}6 = 45$ kg P. However, it is also possible to hypothesize that subsequent fellings occurred on the same land in 1860, 1920 and 1970, resulting in the loss of 18, 18 and 15 kg P respectively, a total of 96 kg P. This loss is extremely serious when one considers that Halifax type soils in Halifax County only contain about 96 kg available P/ha. These figures are not unreasonable, as Hornbeck (1978) indicates losses of 27 kg/ha in whole-tree harvests of northern hardwoods.

Clearcutting has been shown to markedly increase the loss of particulate matter and dissolved salts from forest ecosystems (Likens *et al.*, 1977). Conservative estimates suggest that an additional loss equivalent to 0·4 kg P/ha/year may occur.

The figures employed in these calculations are used only to illustrate the argument and should not be seen as being those for any particular part of Nova Scotia. However, they indicate the possibility of serious nutrient depletion from forest ecosystems on nutrient-deficient soils.

4.5. SHORTAGE OF TIMBER FOR SAWMILLS

Although the number of sawmills has decreased markedly from 1401 in year 1861 to about 300 at the present time, many of those that are functioning complain of a shortage of suitable timber. They cannot find an adequate source of good quality timber. This complaint is extremely serious to the province when it is realized that the value of a finished wood product can be several times that of pulp, and the number of people employed can also be greater.

4.6. ANOLOGY WITH OTHER AREAS

Most of western Europe had a 90% forest cover and this forest has been repeatedly cut, cleared and modified so that, at the present time, it is approximately 8% in some countries. The fine holm oak (*Quercus ilex*) forests of the Mediterranean have been down-graded to scrub-dominated barrens known as maquis and garrique; in Germany, Luneburger Heide is an extensive heather-dominated barren which is anthropogenic in origin (Walter, 1973); in Scotland, the Highland forest clearances of the seventeenth century are now extensive and largely unproductive blanket bog; and much of the barren land around Sudbury, Ontario, is probably the product of repeated burning by geochemical prospectors, as well as of the more notorious atmospheric pollution. Nova Scotia is climatically and geologically different from each of these areas, but there is sufficient similarity in terms of both the type of resource and its exploitation to indicate the possibility of a serious downgrade process in the province. It is also known that to reverse this kind of down-grade process is extremely difficult. See, for example, Drinkwater (1957) for a discussion in relation to tolerant hardwood forest in northern Nova Scotia.

4.7. REDUCED ANNUAL INCREMENT

Tree growth rates are a function of species, density, age, soil fertility and climate. Spacing has been shown to stimulate growth rate and fertilizer similarly triggers a rapid response. However, a forest with a sluggish annual increment is in a poor condition, and one with a large increment is producing timber rapidly.

Sample increment borings have been taken from several areas in the province and show a slower growth rate during the last ten years than in the best ten years. The best ten years is used here to indicate the potential for those species of that genotype on that particular type of soil. One area that was examined, dominated by oak and beech of mean age 62 years (maximum 165 years), showed the last 10 years to be 46% of the best. The difference was statistically significant ($P > 0{\cdot}001$) and there was no significant correlation between recent growth rate and tree age (slope $= -0{\cdot}002$) showing that this reduction is not simply an ageing effect.

This kind of observation suggests that there is the potential within the forests to almost double the growth rate, probably by fertilizer application or spacing operations. Studies of this kind need to be undertaken on a more extensive scale.

These figures do not necessarily indicate that there is a reduction in volume growth on these sites, as stem analysis has shown continuing good height growth. It is not possible to calculate the exact volume changes as we do not know the stocking of the stands examined ten years ago [see Forbes (1955), for "interpolation method", which can be used to calculate gross volume].

5. Prospects for the future

In the 1960s and early 1970s, the trend within the province was toward large processing operations, mostly pulp and paper industries, owned by multinational companies. These industries were attracted to generate industrial activity and employment in rural areas. Their mills require large volumes of softwood fibre, some of which is unavailable on land in private ownership and in small units. The Small Tree Act, which stipulated a minimum diameter for cutting, was repealed and various incentives such as cheap stumpage on Crown land were introduced.

More recently, under a Department of Regional Economic Expansion Agreement, the Forestry Sector is to receive substantial funding ($26 million over five years) to improve the management and yield from private land in particular. A Forest Improvement Act was passed by the provincial legislature in 1977, but is effectively inoperative until guidelines are available. These guidelines will be included in a Manual of Forest Practices which is expected to become available in 1979. The manual is being produced by consultants for a Forest Practices Improvement Board. Regional Boards may be established at a later date. Generous funding for silviculture on private lands, road-building, the provision of a new nursery [indigenous or exotic material? Goldsmith and Boudreau (1979)], as well as the salvage and storage of fibre from the budworm-damaged highlands of Cape Breton, should at least stabilize the condition of the forest resource.

At the same time, there are repeated pressures to spray the budworm with insecticide and to spray the hardwoods with herbicide to release softwoods, but these proposals have been opposed by environmental groups. The use of whole-tree harvesting of stem-wood is to be encouraged, but the tops and leaves of trees contain a large part of the total biomass nutrient pool.

6. Nutrient losses that can be expected to occur with more intensive harvesting

The seriousness of nutrient losses in harvesting operations is essentially a value judgement and varies with the nutrient being considered, the type of forest (i.e. its species), the type of harvesting operation, the history of the site, the rotation length, and site conditions.

The critical question facing Nova Scotia is the extent to which the tops of trees and stumps should be used for pulp or energy generation. If we decide to "complete-tree" harvest hardwoods, we should expect to remove additional amounts of nutrients in each rotation.

Young and Carpenter (1967) estimate, for 36-year old red maple in Maine, that each tree represents 59 g N, 11·5 g P, 36 g K and 98 g Ca. These figures are approximately double the weights that would be extracted if just the stem is removed. If we assume a stocking of 1000 trees to the acre (400 trees/ha), then the total nutrient loss in the fibre harvested would be 23·6 kg N, 4·6 kg P, 14·4 kg K and 39·2 kg Ca. There would be additional nutrient losses in run-off if the site is clearcut, especially if stumps were removed.

6.1. VARIATION DUE TO THE NUTRIENT

Some elements are more soluble than others (e.g. 95% of the losses of sodium occur as dissolved substances in run-off; calcium salts, however, are usually less soluble). The natural sources of each element are also variable; for example, calcium comes mostly from weathering, sulphur from aerosols and nitrogen from biological fixation. In Nova Scotian forests, nitrogen-fixation is probably largely restricted to rotting wood and lichens on the trunks of hardwoods.

6.2. VARIATION DUE TO FOREST TYPE

Hardwoods have root systems which exploit a larger volume of soil and therefore probably act as nutrient pumps. They also have a higher lichen and bryophyte cover which generates a limited amount of nitrogen. Alders have a high productivity in their first 20 years and also nitrogen-fixing ability associated with their roots, reaching a peak at about 20 years of up to 300 kg/ha/year reported for Georgia (Turner, Cole and Gessel, 1976). The leaf litter of hardwoods, which is produced annually, has a higher nutrient content than softwoods and decomposes more rapidly, producing a mull-type humus. Nutrient cycling in hardwood forests is discussed by Duvigneaud and Denaeyer-deSmet (1970) and Patric and Smith (1975).

6.3. VARIATION DUE TO HARVESTING

Clearcutting is the enemy of most environmentalists and, when badly carried out, its effects can be disastrous (see, for example, Horwitz, 1974). Even when carefully conducted, it can result in poor regeneration or the regeneration of less desirable shade-intolerant species. The Hubbard Brook experiment in New Hampshire exaggerates the effects of clearcutting because a herbicide was also used. However, it shows the regeneration of pioneer species from stump sprouts and serious nutrient losses over the first ten years (Likens *et al.*, 1977, 1978):

	Cut	Control	
NO_3	499	43	kg/ha lost in stream water over ten years
Ca	450	131	
K	166	22	

They report, "For nitrogen this loss represents about 28% of the total nitrogen stored within the ecosystem previous to cutting and is about six times the amount that is taken up annually by vegetation . . .". The net addition of nitrogen occurred at an average rate of 2·5 kg/ha/year.

Kimmins and Krumlik (1976) and Kimmins (1977) have examined the effects of the type of harvesting, rotation length and the natural rate of replacement on the site nutrient capital. A simplification of one of his figures is presented as Figure 3.

6.4. VARIATION DUE TO THE HISTORY OF THE SITE

Much of Nova Scotia, having been logged in some way for about 350 years, has had a longer history of exploitation and therefore also of nutrient removal than most parts of North America. Consequently, direct comparisons with other areas in North America with shorter logging histories and/or deeper or better soils must be suspect and, in each comparison, the disadvantages lie with the situation to be found in Nova Socotia.

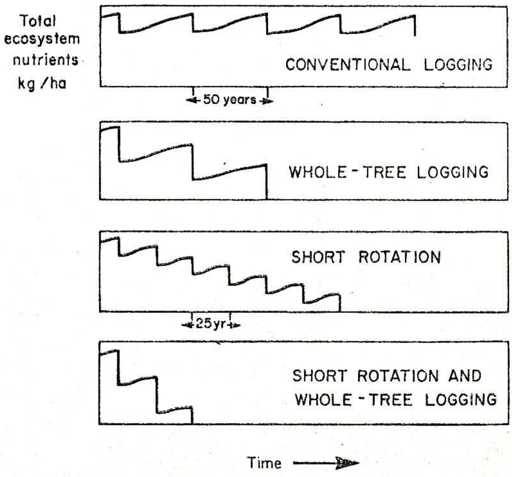

Figure 3. Diagrammatic relationship between the type of harvesting operation, rotation length and site nutrient capital on nutrient deficient sites (after Kimmins, 1977).

6.5. THE ROTATION LENGTH

Shortening of the rotation increases the frequency with which the substantial nutrient losses documented by Likens *et al.* (1977) occur (see Figure 3). The costs of artificial reforestation, if necessary, are also incurred more frequently. The period of time over which nutrient losses in harvesting and replanting are made good by slow, natural processes is shortened.

6.6. SITE CONDITIONS

In Nova Scotia, there is considerable variability between the poorest and best forest soils. For example, Halifax series soils which are moderately coarse-textured can be compared with Lawrencetown series soils which are fine-textured but in Halifax County are poorly drained. Halifax series soils occupy 28% of the county, whereas Lawrencetown series soils occupy less than 1% of Halifax County. Even when they are suitable for agriculture, liming is recommended because of artificial drainage (Cann *et al.*, 1965; MacDougall *et al.*, 1963).

	Depth (cm)	kg/ha			
		Ca	Mg	K	P
Halifax series	43+	489	227	263	96
Lawrencetown series	122+	69 113	1810	2278	2927
Ratio L/H	3	141	8	9	41

These figures indicate the substantial variability within one county of Nova Scotia. It is unlikely that nutrient depletion would ever become a problem on Lawrencetown series soils, however frequently and by whatever means they are harvested. On the other hand, Halifax series soils which have been burnt and/or cut over several times must be considered extremely vulnerable to nutrient depletion.

6.7. HOW MUCH FERTILIZER WILL BE NEEDED?

The answer to that question has to be a qualified one. To bring nitrogen and phosphorus levels up to those in Prairie soils would require at least 20 times the amount of N and P in most Nova Scotian forest soils. However, to bring class 6 forest land (productivity 11–30 cu ft/acre/year; 0·77–2·1 cu m/ha/year), where the constraint on growth is caused by nutrient-deficiency rather than exposure or restrictions to root development, up to class 4 forest land (productivity 51–70 cu ft/acre/year; 3·6–4·9 cu m/ha/year) might require 100 lb/acre (112 kg/ha) N, 50 lb/acre (56 kg/ha) P and 200 lb/acre (224 kg/ha) Ca. These figures are based on soil sampling we have carried out in selected sites and analyses conducted by the Nova Scotia Department of Agriculture Laboratories in Truro. The amounts applied will necessarily be a function of the frequency of application. It must also be remembered that some fertilizers require the addition of lime simply to neutralize the fertilizer acidity. For example, ammonium nitrate (33·5% N) requires 60 kg of limestone per 100 kg of fertilizer.

7. Discussion and conclusion

Forest management in Canada has attracted increasing attention in the last few years, culminating in the Reed Report (1978). Their conclusions include the statement:

> "There is still virtually nothing being done to return neglected cutover lands or decadent stands to productive status, in spite of the fact that much of this is good site and is within relatively short distances of existing processing plants."

At the provincial level, there has been a review by the Nova Scotia Forest Products Association (1970) and a federal government study emphasizing the need for a program of silviculture (Stewart *et al.*, 1972) which considers ownership, cover types, age class and volume of the forests of Nova Scotia, and concludes:

> "It is not at all certain that there are adequate volumes of suitable timber to meet specific needs such as for sawlogs or veneer logs."

More recently, a task force set up by the Provincial Government in relation to the budworm outbreak in eastern Nova Scotia has published its findings (MacDonald, 1978). They indicate that the basic problem is that the annual allowable cut of softwood in the future, having been reduced by the budworm, will satisfy only approximately 50% of the demand. They recommend an aerial spray program and a long-term forest improvement program involving spacing and planting.

An ecologist is only able to find sketchy information for Nova Scotia. Consequently, the discussion above is based on cautious extrapolation. My value judgement is that there will be real problems with the intensive harvesting of hardwoods and "surplus" softwoods for energy production, but it is difficult to predict how extensive or severe the problem will be. The soil is the resource that needs to be managed just as much as the crop which grows on it. Complete-tree harvesting, if practised in Nova Scotia, will require extensive fertilization in order to maintain site productivity and in order to improve yields.

The historical survey shows how repeated heavy cutting and burning have downgraded the forest resource in Nova Scotia. At the same time, the processing industries have shifted from species to species as the resource has adjusted to the level of exploitation. White pine as the major species was replaced by red spruce and this species by balsam fir. Similarly, hard maple is being supplanted by red maple. In the future, shorter rotations of fir and spruce will presumably be used as well as coppice hardwood, for pulp, fibreboard and biomass energy. Forestry will continue in business, but our options for the future will have been reduced.

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