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# LONG-TERM PRODUCTIVITY OF BOREAL FOREST ECOSYSTEMS: AN ANNOTATED BIBLIOGRAPHY

M.E. Taylor*, H.M. Kershaw**, and D.N. Nixon*

## INTRODUCTION

Within Ontario, the importance of managing forest resources on an ecosystem framework has been identified and a broad program to provide background information for management has been developed. Fluctuations in tree species composition occur in response to natural events such as fire, blowdown, insects, disease, and aging. Other forest changes result from human activities, particularly from logging. Impacts are related to the size of the area cut, postlogging treatments, planting, tending, thinning, and protection activities (pest and fire management). Secondary effects associated with the development of logging roads, or the modification of drainage patterns and landscape level impacts that modify hydrologic and nutrient cycles, may also occur.

The boreal forest region consists of a variety of forest ecosystems that differ in terms of topographic expression, plant species composition, and soil conditions. Soils range from the relatively nutrient-rich, deep, well-drained, fine-textured lacustrine silts and clays of former glacial Lake Agassiz to frequently shallow, poorly to well-drained, coarse-textured tills and outwash sands. Productivity of forest ecosystems varies with species composition, local climate, soil texture, drainage, soil depth, and site history. Forest humus, ground cover, and microclimatic conditions have a strong influence on nutrient cycling and associated tree growth within the boreal forest.

Harvesting methods on boreal forest sites can significantly influence long-term biological productivity and nutrient status through such physical site impacts as soil compaction, rutting, erosion (particularly on shallow soils and on steep topography), mixing of nutrient-rich soil surface horizons with nutrient-poor lower horizons (during site preparation activities), destruction and/or loss of surface organic matter, and removal of nutrient-rich vegetation such as twigs and leaves (during harvesting or site preparation). Harvesting methods may also influence soil microflora and fauna, which in turn may influence long-term soil/site productivity. Finally, timber harvesting and management activities can have influences on the infinite variety of life forms in boreal forests. For example, forestry operations influence the availability of nest sites for forest birds and the provision of browse for moose. Beaver affect riparian habitats through modification of succession, and small mammals such as voles are important in the distribution of seeds, fungal spores, and mycorrhizae. Forest management practices may remove suitable habitat for small but important components of boreal ecosystems.

Considerable research has focused on assessing the productivity of northern temperate and boreal ecosystems over the past 20 years. Results from this research have been summarized in refereed journals, unpublished government reports, university theses, and file reports. The focus of these papers may assist managers and scientists in evaluating where future gaps in information are likely to occur.

Public concern about the forest environment has never been greater than at present. This was recently addressed in Ontario by the Class Environmental Assessment of Timber Management, and by frequent news media coverage of such topics as old-growth forest preservation, clear-cutting,

* Geomatics International Inc., 3370 South Service Road, Burlington, Ontario L7N 3M6
**Devlin Consulting Services, 120 Roxborough Dr., Sudbury, Ontario P3E 1J7

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chemical use in forests, biodiversity, and long-term productivity. The Canadian Forest Service (CFS) and the Ontario Ministry of Natural Resources (OMNR) are pursuing research in these areas to develop a better understanding of the integrity and diversity of forests and to provide guidance toward managing forests for sustainable long-term productivity.

A review of the problem has indicated that the main issues and concerns about forest practices are associated with:

i) removal of nutrients contained in biomass from sites and the potential for reductions in long-term sustainable productivity;

ii) physical changes to the soil associated with the effects of heavy equipment on mineral and organic soils, particularly in compaction, soil mixing, and modification of drainage patterns;

iii) impacts of clear-cutting and how they compare to natural, large-scale disturbances such as wildfire;

iv) impacts of road building on erosion, stream water quality, and increased access by people for recreational activities;

v) potential losses of biodiversity associated with changes in species composition and forest structure;

vi) changes in patch size and age distributions for various ecosystem components; and

vii) loss of old-growth forests and other critical habitats.

A major concern expressed during the Class Environmental Assessment hearings was the impact of full-tree harvesting, whereby trees are skidded to the roadside, delimbed, and the slash piles are burned or left. This practice concentrates nutrients at the roadside, depletes forest soils, and may cause potential reductions in site productivity. Intensive site preparation by blading concentrates the remaining superficial forest floor materials into windrows, leaves wide strips of exposed mineral soil, and increases the potential for site degradation. Other concerns about site degradation include the impacts of soil compaction and prescribed burning.

A federal–provincial Technical Working Group has been established to coordinate an investigation of the maintenance of long-term productivity of boreal ecosystems in relation to harvesting practices, such as the full-tree method. The multiple working hypothesis approach suggests that a number of primary environmental factors could be responsible for a reduction in productivity, e.g., low inherent nutrient regime, moisture regimes too dry or too wet, poor soil aeration, soil thermal regimes too warm or too cool, etc. The species that are emphasized by this Technical Working Group are conifers, including jack pine (*Pinus banksiana* Lamb.) and black spruce (*Picea mariana* [Mill.] B.S.P.). Frequently these species occur on nutrient-poor sites. Following harvesting, these conifer dominated stands often show shifts in composition toward mixedwoods and hardwoods (Hearnden 1993), which are not preferred species for the Ontario forest industry. To avoid duplication of effort and to provide a focus for each agency, the CFS is concentrating its research on jack pine while the OMNR is focusing on black spruce .

## Project Objectives

The project objectives are derived from memoranda and meetings of the Sustainable Productivity of Forest Ecosystems Technical Working Group held over the last 2 years. The general objective is:

> "To facilitate federal and provincial cooperation in research on the sustainable productivity of forest ecosystems and to develop ecosystem management practices."

Within this overall objective there are a number of subsidiary themes:

i) coordination and linkages;

ii) information synthesis and needs analysis; and

iii) technology and information transfer.

A short summary of the scope of each of these subsidiary themes is presented below.

## Coordination and Linkages

There are three general aims of this part of the program:

i) to coordinate research efforts and promote cooperation in the area of sustainable productivity of forest ecosystems. This is part of the activity designed to satisfy information requirements that have been identified under the Ontario Sustainable Forestry Initiative, the Ontario Environmental Assessment Process, and the CFS Strategic Plan;

ii) to develop experimental designs and protocols for studying forest ecosystems; and

iii) to provide linkages with research programs on other aspects of forest ecology (e.g., wildlife) and linkages with policy development.

## Information Synthesis and Needs Analysis

Resource managers and field staff have limited access to, and limited time to keep up with, the current literature. Presently they are being asked to manage within the broader forest ecosystems rather than practice traditional stand-oriented management. Relative papers are now increasingly being published in other traditional forestry journals, thereby creating a need for concise summaries of current literature and associated research results. The program will also facilitate opportunities for scientists and field staff to work together to address current and projected concerns that link forest practices to the maintenance of long-term productivity. The information and needs analysis objective has been subdivided into the following five tasks:

i) to provide an understanding of the structure and function of forest ecosystems;

ii) to fill information gaps for impacts of anthropogenic and natural disturbances;

iii) to synthesize information;

iv) to review current research in the context of provincial, national, and international needs; and

v) to identify new directions and opportunities for research.

### Technology and Information Transfer

There are always concerns with accurate information transfer and the lag time that commonly limits the adoption of new technologies and procedures. With the advent of environmental assessment procedures comes the increasing need for effective and efficient monitoring and response to any identified concerns. As such, the following two tasks were identified as critical components of this program:

i) to develop cooperative approaches to the synthesis and marketing of research results and technologies to forest managers, environmental specialists, and other clients; and

ii) to assist in the development and monitoring of technology transfer output, client relationships and initiatives, and mutual information exchange.

The Technical Working Group, consisting of six scientists with active involvement in the area, provides equal representation from OMNR and CFS. A Steering Committee, consisting of one director from the OMNR and one from the CFS, provides general management direction. Scientists from other organizations can be appointed to the Technical Working Group for specific terms.

### Approach

The following approaches have been initiated by both agencies:

i) ecosystem classification and dynamics;

ii) development of interim guidelines and indicators;

iii) ecosystem nutrient cycling and modeling;

iv) biomass removal experiments; and

v) studies of the ecophysiology of seedlings.

The Technical Working Group is comprised of research scientists from the Canadian Forest Service office in Sault Ste. Marie, Ontario and the Ontario Ministry of Natural Resources research offices in Sault Ste. Marie (Ontario Forest Research Institute) and Thunder Bay (Centre for Northern Forest Research Institute). Members are listed in Table 1.

**Table 1.** Sustainable Productivity of Forest Ecosystems Technical Working Group

| Canadian Forest Service | Ontario Ministry of Natural Resources |
|---|---|
| Dr. John Jeglum (co-chair) | Mr. Dave Morris (co-chair) |
| Dr. Neil Foster | Dr. Alan Gordon |
| Dr. Ian Morrison | Dr. Nadarajah Balakrishnan |

## OBJECTIVES

Generally, the objectives of this study were to address the information synthesis and needs analysis objectives of the Long-term Productivity of Boreal Ecosystems Project. More specifically, the objective was to prepare an annotated bibliography of literature that assessed long-term productivity in boreal jack pine and black spruce ecosystems and evaluated the impact of current harvesting practices on this productivity. This bibliography includes literature on nutrient cycling, site productivity, silvicultural operations, harvesting operations, seedling ecophysiology, and wildlife population dynamics in harvested and nonharvested forests. The range of literature retrieved from the journals will contribute to identifying past and current research, minimize future duplication of research effort, and identify major gaps in the knowledge base with respect to long-term productivity in boreal ecosystems.

## METHODS

The primary sources of information included in this annotated bibliography were CD-Rom based databases held by the University of Toronto. These databases include: Forestry Tree (TREECD) from 1939 to 1991; Biological Abstracts (CAB) from 1984 to 1991; Microlog, a data base containing federal and provincial research literature, for the period January 1982 to December 1992; and Dissertation Abstracts International (DAI), which contains bibliographic citations and abstracts for North American doctoral dissertations and some masters theses, from 1861 to June 1992. Each of these data bases was searched and relevant citations downloaded to disk. Disk files were then translated into Pro-Cite format using Biblio-Link to Silverplatter software and incorporated into a Pro-Cite data base. Pertinent articles were also selected from recent issues of the Canadian Journal of Forest Research (1991 to 1993) and The Forestry Chronicle (1990 to 1993). Abstracts are from the authors' summaries.

In addition to the CD-ROM searches, existing bibliographies were reviewed. These included: Whole-tree Harvest – Nutrient Relationships: A Bibliography (Kimmins et al. 1985); Growth and Yield of Northwestern Ontario Boreal (Coniferous) Forest Species: An Annotated Bibliography (Bell et al. 1989); The Effects of Forest Management Practices on Nongame Birds: An Annotated Bibliography (Nietfeld and Telfer 1990); and Petawawa National Forestry Institute (1987, 1989, 1991), Great Lakes Forest Research Centre/Forestry Centre (1991, 1992), and Northern Forest Research Centre (1976, 1988, 1991) bibliographies.

Numerous citations were provided by researchers responding to the project questionnaire. Additional lists were provided by scientists in the CFS and the University of Toronto. Reference lists from relevant exhibits presented during the recently completed Class Environmental Assessment of Timber Management in Ontario were provided courtesy of the OMNR.

To identify literature relating to recent research conducted at the university level, undergraduate and graduate theses were reviewed during visits to the University of Toronto, Lakehead University, and the University of Guelph. While many undergraduate theses exist, these are not readily available outside the academic institution for which they were written and thus were not included in the citations. The peer review and quality of these publications varied. Those students who continue their forestry careers in research will later publish reviewed and refereed papers on related subject material. Where authors published many papers on the same subject material, only the most recent ones were selected for inclusion in the bibliography. Progress reports were not included where refereed papers on the same subject material were available. While the general focus of this annotated bibliography deals with boreal ecology, a few papers relevant to the principles of harvesting and nutrient loss from other forested ecosystems or that have employed innovative methodology and analysis techniques are included.

The latest version of the bibliographic program, Pro-Cite 2.02, was used. This new version provides direct downloading to WordPerfect, thereby allowing for easy incorporation of bibliographic citations into text-based documents.

Biblio-Link to Silverplatter, a companion software program to Pro-Cite, was also utilized to translate CD-Rom based databases into Pro-Cite format.

The annotated bibliography is available on a 3.5-in., low-density diskette, which contains two compressed, self-extracting files, WORDPERF.EXE in WordPerfect 5.1 and PCITEBOR.EXE in Pro-Cite 2.02. To access either file, copy the desired file to a directory established on a computer hard drive. Make the newly created directory current and, at the prompt (>), type either wordperf or pcitebor and then press the return key. The files will decompress and result in sizes of 503,823 bytes and 1,032,995 bytes for the WordPerfect and Pro-Cite files, respectively. Assuming that the user has the appropriate software packages, keyword searches can be conducted utilizing the corresponding electronic files.

## ANNOTATED BIBLIOGRAPHY

The complete annotated bibliography found in NODA File Report No. 8 contains a total of 390 bibliographic citations. The format of the citations follows that used by the Canadian Journal of Forest Research.

Many articles cover at least two and often three subject areas within this bibliography. Readers are encouraged to search the electronic database provided either in Pro-Cite or WordPerfect for rapid access to bibliographic information on a particular subject area of interest. Key papers by major subject headings are listed by citation to provide an overview of the type of material included in this bibliography.

### Nutrients

The bibliography contains approximately 120 articles dealing with nutrients in northern forests. Of these, two-thirds are directly related to the importance of nutrients in the productivity of these forests. These publications focus on nutrient-poor sites, nutrient budgets, nutrient management, fire effects on soil nutrients, effects of clear-cutting, growth and yield comparisons for different silvicultural treatments, effects of full-tree harvesting, nutrient status of ground cover after harvesting, and the effects of harvesting and fast growing species on nutrients.

### Silviculture

Many references in the bibliography deal with silvicultural strategies and their impacts on future site productivity. These references discuss traditional silvicultural subjects including direct seeding, the impacts of full-tree harvesting on forest productivity and site quality, black spruce regeneration, and site productivity responses to alternative silvicultural treatments. In addition, some of the papers discuss the critical silvics of plant species, which influence the effectiveness of silvicultural operations based on the timing of applications. Other papers focus on the influence of silvicultural operations on forest soil nutrient availability and cycling. A few focus on timber management effects on wildlife populations.

#### *Harvesting*

These records contain references to harvesting methods and their impact on long-term site productivity. They include discussions of fire effects on soil nutrients on clear-cut, full-tree harvested sites; the biological and nutritional implications of harvesting; and the impact of harvesting on soil compaction, water quality, timber yield, and nutrient budgets.

#### *Site Preparation*

A number of records concern site preparation methods and their impact on long-term site productivity. References include discussions of direct seeding; the impact of prescribed fire; comparisons of tree growth after different site preparation treatments; and the effects of site preparation methods on soil compaction, nutrient cycling, and nongame birds. They also include summaries of operational field trials.

#### *Tending*

Five references focus on tending and its effect on the future forest. The papers discuss methods for determining the needs for stand tending, methods for site amelioration in fast growing tree plantations, and the effect of monocultures on site productivity.

### Seedling Ecophysiology

There are approximately 27 citations dealing with seedling ecophysiology; however, many of them address the growth of seedlings rather than the physiological mechanisms involved. Subject material covered includes mycorrhizae and seedling survival, soil compaction and its affect on seedling growth, species shifts associated with natural regeneration, morphological changes in response to competition, and nutrient absorption during seedling establishment.

### Mycorrhizae

Mycorrhizae are known to influence the establishment and growth of jack pine and black spruce. Eight references on this subject are included in the bibliography. Two papers address the inoculations of mycorrhizae on jack pine and black spruce; one paper discusses phosphorus concentrations and mycorrhizae development.

### Nutrient-poor Sites

Nutrient-poor sites are discussed specifically in six of the papers included in this bibliography. These address nutrient cycling, the effects of full-tree harvesting on site productivity, and the characterization of site and stand conditions.

### Wildlife

Eighteen general wildlife references are included in this bibliography. These include articles on the effects of fire on invertebrates, birds, and animals; impacts of the use of *Bacillus thuringiensis* (B.t.) or insecticides on bird and mammal populations in jack pine plantation forests; and changes in small mammal populations following clear-cutting in black spruce forests. The linkages between logging and wildlife ecology are discussed in both general and specific terms. For example, one scientist studied the influence of habitat diversity on the abundance and diversity of small mammals in jack pine forests. The references that deal with wildlife in general include the following:

#### *Mammals*

Eleven papers deal specifically with mammals, harvesting pattern and habitat diversity, and the effects of fire and insecticides.

#### *Birds*

The bibliography includes 15 references to birds in the boreal forest ecosystem. These cover the use of herbicides (fenitrothion, Matacil®, and B.t.) and the effects of harvesting and fire on birds, harvesting pattern on the fragmentation of habitat, and forest management on soil insects.

#### *Insects*

Five key insect references were selected for inclusion in the bibliography. These cover the following broad topics: harvesting effects on insect populations, the effect of forest fragmentation and fire on insect populations, and a review of methods for assessing insect populations.

### Modeling

There are 27 articles on modeling in the boreal forest. These vary from modeling floristic composition following fires of different frequencies and intensities through to modeling the implications of intensive forest management and alternate silvicultural techniques on growth and yield. Other articles model the effect of harvesting on site productivity and nutrient pools. These papers include:

#### *Jack Pine*

Publications that refer specifically to jack pine focus on the impact of different harvesting systems on growth and yield, and on the assessment of current yields.

#### *Black Spruce*

Publications dealing with black spruce focus on the impact of different harvesting systems on the growth and yield of black spruce, and on the assessment of current yields.

A more detailed index to papers included in the bibliography follows the annotated references.

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## LITERATURE CITED

Ballantyne, B.A.; Mitchell, M.H. 1989. Bibliography/liste des publications 1986–1987. For. Can., Petawawa Natl. For. Inst., Chalk River, ON. Inf. Rep. PI-X-87E/F.

Bell, F.W.; Hanmore, C.J.; Willcocks, A.J. 1989. Growth and yield of northwestern Ontario boreal (coniferous) forest species: An annotated bibliography. Ont. Min. Nat. Resour., Northwestern Ont. Forest Tech. Devel. Unit, Thunder Bay, ON. Tech. Rep. 31.

Boross, P.A.; Mitchell, M.H. 1991. Bibliography: 1988–1990. For. Can., Petawawa Natl. For. Inst., Chalk River, ON. Inf. Rep. PI-X-106E/F.

Dendwick, F.M.; Stevenson, G.R.; Rentz, C.L.; Gorman, J.R., compilers. 1980. Forest research bibliography, 1968–1975 supplement. Can. For. Serv., North. For. Res. Cent., Edmonton, AB. Inf. Rep. NOR-X-152.

Forestry Canada. 1991. 1990 bibliography. Ont. Reg., Great Lakes For. Cent., Sault Ste. Marie, ON. Inf. Rep. O–X–416.

Forestry Canada. 1992. 1991 bibliography. Ont. Reg., Great Lakes For. Cent., Sault Ste. Marie, ON. Inf. Rep. O–X–424.

Hearnden, K.W.; Millson, S.V.; Wilson, W.C. 1992. A report on the status of forest regeneration by the Ontario Independent Forest Audit Committee. Ont. Min. Nat. Resour., Sault Ste. Marie, ON. 117 p.

Kimmins, J.P.; Binkley, D.; Chatarpaul, L; de Catanzaro, J. 1985. Whole-tree harvest – nutrient relationships: A bibliography/Exploitation des arbres entiers – rapport des eléménts nutritifs: étude bibliographie. Can. For. Serv., Petawawa Natl. For. Inst., Chalk River, ON. Inf. Rep. PI-X-60E/F.

Leroy, D.A. 1991. Northern Forestry Centre publications, 1987–90. For. Can., North. For. Cent., Edmonton, AB. Inf. Rep. NOR-X-321.

Nietfeld, M.T.; Telfer, E.S. 1990. The effects of forest management practices on nongame birds: An annotated bibliography. Can. Wildl. Serv., Western and Northern Region, Edmonton, AB. Tech. Rep. Series No. 112.

Samoil, J.K.; Tuttle, G.B. 1988. Northern Forestry Centre publications, 1980–86. Can. For. Serv., North. For. Cent., Edmonton, AB. Inf. Rep. NOR-X-297.

Yapa, A.C.; Mitchell, M.H. 1987. Bibliography/liste des publications pour les années 1970–1985. Can. For. Serv., Petawawa Natl. For. Inst., Chalk River, ON. Inf. Rep. PI-X-70E/F.

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