

Synthesis of silviculture options, costs, and consequences of alternative vegetation management practices relevant to boreal and temperate conifer forests: Introduction

by F. Wayne Bell¹, Nelson Thiffault², Kandyd Szuba³, Nancy J. Luckai⁴ and Al Stinson⁵

ABSTRACT

In 2007, a multi-agency, multi-disciplinary team from across Canada embarked on an exercise to synthesize knowledge about forest vegetation management alternatives and their use in northern forests. This exercise involved: (1) updating the Canadian Forest Pest Management database, (2) synthesizing relevant forest vegetation management literature, (3) conducting stand-level wildlife, wood quality, yield, and benefit-cost analyses, (4) conducting landscape-level analyses to determine the effects of a systematic reduction in herbicide use on forest management objectives, and (5) transferring the relevant information to forest managers. The results are presented as ten papers in this special issue of *The Forestry Chronicle*.

Key words: forest economics, forest vegetation management, forest growth and yield, forest modelling, social acceptability, wildlife habitat

RÉSUMÉ

En 2007, une équipe multi-agences et multidisciplinaire pancanadienne a entrepris d'effectuer la synthèse des connaissances sur les différentes options de contrôle de la végétation en forêt dans le contexte des forêts nordiques. Cet exercice a nécessité : (1) la mise à jour de la Base de données relatives à la lutte contre les insectes ravageurs, les maladies et la végétation compétitrice dans les forêts au Canada, (2) la synthèse de la littérature pertinente sur le contrôle de la végétation forestière, (3) des analyses à l'échelle du peuplement sur la faune, la qualité du bois, les rendements et l'aspect coût-bénéfice, (4) des analyses à l'échelle du paysage afin de déterminer les impacts d'une réduction systématique de l'utilisation des herbicides chimiques sur l'atteinte des objectifs d'aménagement, et (5) le transfert de connaissances aux aménagistes et sylviculteurs. Les résultats de cet exercice sont présentés dans dix articles qui forment ce numéro spécial du *Forestry Chronicle*.

Mots-clés : économie forestière, contrôle de la végétation, croissance et rendements forestiers, modélisation forestière, habitats fauniques, acceptabilité sociale

Background

In 1983, the Canadian Institute of Forestry / Institut forestier du Canada Executive Committee (CIF/IFC 1983) approved the following as part of a policy statement:

“Until continuing research can provide viable alternatives to chemical pesticides, foresters are dependent upon them to achieve many forest management objectives. Without their availability, it is certain that forest production goals set for the year 2000 will not be met; the annual allowable cut from productive forest land will be decreased, and the viability of the forest industry will be substantially reduced. Given this scenario, the contribution of the forest industry to the socio-economic needs of this country will not be sustained or enhanced to the obvious detriment of future generations of Canadians.”

Since the time that policy was published, substantial investments have been made by governments and the forest industry across Canada to investigate the feasibility and efficacy of alternatives to herbicides (Thompson and Pitt 2003). As well, forest management policies have shifted from a focus on *timber management* and the cultivation of crop trees to policies based on *sustainable forest management* and *forest ecosystem management* (e.g., Grumbine 1994, Christensen *et al.* 1996, Baker 2000, Kneeshaw *et al.* 2000, Chapin *et al.* 2002, Burton *et al.* 2003, Harvey *et al.* 2003, Kimmins 2004, Thompson and Harestad 2004) with much broader objectives. This shift has led to related changes in the definition of forest vegetation management (FVM).

During the period when forest management focused on fibre production, Walstad and Kuch (1987) defined FVM as “the practice of efficiently channeling limited site resources

¹Ontario Forest Research Institute, Ontario Ministry of Natural Resources, 1235 Queen Street East, Sault Ste. Marie, Ontario P6A 2E5. E-mail: wayne.bell@ontario.ca

²Direction de la recherche forestière, Ministère des Ressources naturelles et de la Faune du Québec, Québec, QC G1P 3W8, and Associate Member, Centre d'étude de la forêt.

³Kandyd Szuba, EACOM Timber Corporation, 100 Old Nairn Rd., Nairn Centre, ON P0M 2L0.

⁴Nancy J. Luckai, Faculty of Natural Resources Management, Lakehead University, 955 Oliver Rd., Thunder Bay, ON P7B 5E1.

⁵Southern Science and Information, Ontario Ministry of Natural Resources, 3301 Trout Lake Rd., North Bay, Ontario P1A 4L7.

into usable forest products rather than into noncommercial plant species". When the concept of sustainable forest management was introduced, Wagner (1994) expanded the definition to include "managing the course and rate of forest vegetation succession to achieve silvicultural objectives". Nonetheless, forest management plans that have embraced the concept of ecosystem management still rely on silviculture to achieve a variety of objectives, such as producing fibre or non-timber forest products, maintaining ecosystem services, and providing wildlife habitat. Therefore, we propose that the definition of FVM be further expanded to "managing the course and rate of forest vegetation succession to achieve forest management objectives".

To choose effective, economically viable, ecologically responsible, socially acceptable approaches for FVM without compromising any of the desired management objectives, resource managers require up-to-date information about available FVM practices and alternatives. This special issue of *The Forestry Chronicle* was compiled to provide an overview and synthesis of the published information on FVM practices, to fill gaps in knowledge about key issues relevant to ecosystem management, and to identify the significant remaining gaps.

The impetus for this work was a request in 2007 from the Agricultural Research Institute of Ontario (ARIO) for a synthesis of information about FVM practices. Since none of the research agencies in Canada had all of the experts required to address the full spectrum of issues, a multi-agency partnership was developed. The partners focused on providing answers to commonly asked questions related to releasing the most common boreal and temperate conifer species (i.e., black spruce [*Picea mariana* (Mill.) BSP], white spruce [*Picea glauca* (Moench) Voss.], jack pine [*Pinus banksiana* Lamb.], lodgepole pine [*Pinus contorta* Douglas ex Loudon], red pine [*Pinus resinosa* Ait.], and white pine [*Pinus strobus* L.]) from herbaceous and woody competitive vegetation, or preventing that competition altogether.

Preparing the synthesis involved: (1) updating the Canadian Forest Pest Management database (described in more detail below), (2) synthesizing relevant forest vegetation management literature related to ecological, efficacy, environmental, and social issues, (3) conducting stand-level wildlife (i.e., songbird and small mammal), wood quality, yield, and benefit-cost analyses, and (4) conducting landscape-level analyses to determine effects of a systematic reduction in herbicide use on forest management objectives. As well, efforts were made to transfer the resulting information to forest managers. The results of this synthesis work are presented in the 10 papers that follow this introduction, and are summarized briefly here.

Interestingly, a similar initiative has recently been carried out in Europe. In their introductory paper to a special edition of the *European Journal of Forest Research*, Ammer *et al.* (2011) conclude that the effects of FVM vary with initial stand composition (i.e., target and non-crop species at a given stand age), functional group of the competitor species, and the level of available resources, themes that are also covered in this special issue. Furthermore, McCarthy *et al.* (2011) identify social issues and public perception as one of several information gaps relating to FVM that remain to be addressed by European scientists and managers. We believe this conver-

gence of key issues related to FVM, emerging from different continents, strengthens the relevance of the collection of papers presented here.

Update the Canadian Forest Pest Management Database

Much of the information presented in the papers by Bell *et al.* (autecology), Wiensczyk *et al.* (efficacy), Swift *et al.* (environment) and Wyatt *et al.* (social concerns) in this special issue was extracted from the Canadian Forest Pest Management (CFPM) Database, which, as part of the synthesis project, was updated in 2008 with 660 new scientific publications from academic, industry, and government research organizations. The CFPM database was a fully interactive, publicly available, database of scientific literature citations and abstracts pertaining to many different aspects of forest management in Canada. The topics covered included efficacy, environmental acceptability, and economic aspects of various FVM techniques.

Synthesize Relevant Literature

Four reviews were conducted to address questions related to competitive species, silvicultural effectiveness of treatment alternatives, and environmental and social issues associated with the alternatives.

What species compete with boreal and temperate forest conifers?

Bell *et al.* (2011b, this issue) provide a list of 71 plant species that are likely to compete with boreal and temperate forest conifers. The authors provide an overview of where to find information about the autecology of these species and suggest how this information can be applied in resource management. They also discuss approaches for maintaining and updating the information, and improving its availability through plant trait databases, and identify the associated knowledge gaps. For a recent overview of mechanisms and dynamics of crop tree competition by neighbouring vegetation, Bell *et al.* (2011b) recommend that resource managers review Balandier *et al.* (2006).

What are the alternatives and their silvicultural effectiveness?

Synthesizing the results of research carried out in Canada and elsewhere for the past two decades, Wiensczyk *et al.* (2011, this issue) discuss (i) the survival and growth benefits to crop trees of controlling competing vegetation, (ii) vegetation management options, and (iii) vegetation management practices. The practices that can influence vegetation responses include silvicultural and harvesting systems, and physical, thermal, cultural, and chemical treatments. They suggest that the effectiveness of treatments may need to be re-evaluated where guidelines for retention of standing residual trees and downed woody debris are implemented, where timing restrictions on operations are imposed, and where road reclamation may preclude re-entry into stands for FVM. These requirements could potentially affect the suite of vegetation management approaches that can be used regardless of other considerations for a given site.

What are the environmental consequences of using silviculturally effective alternatives?

In their review, Swift and Bell (2011, this issue) compare the potential environmental effects of forest vegetation management treatments on a variety of abiotic and biotic values including air quality, water quality and quantity and fish habitat, soil and soil nutrients, plant diversity and wildlife population dynamics and habitat. Their paper builds on previous work by bringing the results together into an updated, more comprehensive overview of the effects of a variety of forest management practices on these values.

With respect to abiotic indicators (such as air, water, and soil) most FVM treatments have the potential to produce greenhouse gases. In addition, treatments such as prescribed fire release chemicals (e.g., mercury) that are naturally found in forests into the air or water. As well, some treatments (e.g., prescribed fire and mechanical site preparation) have the potential to expose mineral soil and release particulate matter into the air or water. Finally, the application of herbicides involves release of synthetic chemicals into the forest environment. Overall, existing regulations and implementation of best management practices reduce the effects of FVM treatments on abiotic indicators.

With respect to plant diversity and wildlife, a full range of light to severe disturbances is required to provide habitat for all species that occur within boreal and temperate forests. Some species are adapted to small, highly disturbed conditions while others require large tracts of infrequently disturbed forests. Swift and Bell (2011) recommend that resource managers conduct landscape-level analyses to optimize the size, intensity, and timing of disturbances to accommodate the needs of various plant and wildlife species.

What social issues are associated with using silviculturally effective alternatives?

Wyatt *et al.* (2011, this issue) investigate the social framework of forest vegetation management, describing a range of issues that resource managers could consider as they prepare plans and decide among alternative treatments. In particular, they discuss their findings with respect to the changing social and environmental context for resource managers, which includes the continual evolution of public values, risk perceptions, and opinions. The authors explain how the social acceptability of vegetation management alternatives is based on context, risk, aesthetics, trust, and knowledge, and why judgements about acceptability change over time and among situations. They further stress that the available information about the benefits and disadvantages of vegetation management options can contribute to developing solutions that address public concerns, but that attempts to use technical information to convince the public to accept one pre-determined option over another have rarely been successful.

Wyatt *et al.* (2011) do not identify FVM treatments with the highest public acceptance or models to predict public reactions to forestry options in particular situations. Instead, they seek to assist resource managers by identifying potential social concerns that could arise from FVM-related choices. They suggest that once managers have identified probable

concerns, they can look for ways to address them, whether through changed practices, consultation, information, or some other strategy.

Conduct Stand-Level Analyses

Three stand-level analyses were conducted to complement the efficacy information presented by Weinsczyk *et al.* (2011) and two wildlife indicator-related papers supplement the environmental effects information presented by Swift and Bell (2011).

Are the alternatives silviculturally effective?

Much FVM-related research provides evidence of individual-tree volume increases ranging from 50% to 5500% in northern forests (Wagner *et al.* 2006). These results, although impressive, are not directly scalable to stand-level volumes, which are required for benefit–cost analyses. To address this gap, Bell *et al.* (2011a, this issue) assessed stand-level volume responses for 31 combinations of site, species, and treatments from six studies in Ontario, Canada. Treatment effects on preferred conifer and gross total volumes as well as projections of net merchantable volumes varied with site, species, and treatment. In short, results were influenced by site quality, initial stocking of preferred conifers, stem densities, treatment type, and application timing. Bell *et al.* (2011a) suggest that it is unlikely that any one treatment will be universally effective and recommend that treatment choice be based on site and species ecology, treatment efficacy, and forest management objectives.

Are the alternatives cost-effective?

Homagain *et al.* (2011b, this issue) conducted stand-level benefit–cost analyses of the vegetation management treatments described in Bell *et al.* (2011b). Gross total and merchantable volumes were projected to age 70 years and BUCK-2 software was used to optimize the quantities of sawlogs, pulpwood, and hog fuel. Net present value (NPV), benefit–cost ratio (BCR), and internal rates of return (IRR) were estimated using different discount rates. Overall, aerial herbicide treatments produced the highest NPV, BCR, and IRR. At a 2% discount rate, the aerial herbicide treatments produced more than double (for crop species) and triple (for crop and non-crop species) the NPV compared to other treatment groups. Homagain *et al.*'s (2011b) results for the internal rate of return for all treatments evaluated indicate that these alternatives are economically viable because the rates of return are positive, with aerial herbicide providing the highest rate of return.

Homagain *et al.* (2011a, this issue) conducted an additional analysis based on differences in stem quality and volume and value of fibre produced by planted white spruce 16 years after vegetation management treatments in northwest Ontario. Using the Forest Vegetation Simulator (FVS^{Ontario}) to project total and merchantable volume to age 70 and BUCK-2 to optimize the resulting product mix, Homagain *et al.* (2011b) found that the value of fibre produced in herbicide and mechanically tended plots was up to double that produced in untended control plots.

Are songbirds and small mammals affected by vegetation management alternatives?

Papers by Zimmerman *et al.* (2011, this issue) and McLaren *et al.* (2011, this issue) provide insight to the value of songbirds and small mammals as indicators of change in forest wildlife communities following FVM treatments.

Swift and Bell (2011) note that herbicide applications affect songbird populations by changing available nesting and foraging habitat. Based on their review of the literature, they also report that vegetation changes resulting from herbicide applications have a transient effect on the composition of songbird communities and that coarse measures of avian community response (e.g., species diversity, overall diversity) often show insignificant or positive responses to herbicide applications. Lautenschlager and Sullivan (2002), Guisepppe *et al.* (2006), and NCASI (2009) recommended evaluating treatment effects at the species level in the context of how specific treatments affect habitat for the species. Zimmerman *et al.* (2011) examine abundance of songbirds in relation to habitat within a replicated study 11 years after establishment of the conifer plantations. Vegetation management treatments included aerial application of herbicides (glyphosate and triclopyr), cutting (motor-manual cutting with brush saws and tractor-mounted Silvana Selective®), and untreated controls. Their results suggest that songbirds are sensitive to variation in FVM treatments and therefore are good indicators of the effects of FVM treatments on habitat. As well, they indicate that these effects may be more persistent than previous studies suggest. Zimmerman *et al.* (2011) recommend that songbird monitoring studies continue beyond the expected turnover time (i.e., the life expectancy of the resident population of songbirds at the time the treatment was applied) of the study populations.

McLaren *et al.* (1998) suggested a list of possible wildlife indicator species for monitoring the effects of forest management in boreal Ontario. These included the masked shrew (*Sorex cinereus* Kerr), rock vole (*Microtus chrotorrhinus* Mill.), and eastern chipmunk (*Tamias striatus* L.) for stand-scale monitoring, and the snowshoe hare (*Lepus americanus* Erx.) for forest-scale monitoring. Since then, several difficulties related to mammal monitoring have been identified. Notably, since small mammal populations may fluctuate vastly and unpredictably year-to-year for a variety of reasons (Morris 2005), many years of monitoring or complex designs may be required to detect effects. McLaren *et al.* (2011) report on the dynamics of small mammal and snowshoe hare populations within three longer-term silvicultural studies. Their results suggest that abundant and opportunistic species with wide habitat tolerances were relatively unaffected by variation in the type of vegetation management treatment, while species preferring open habitats thrived in herbicide-treated areas.

Other species declined in treated areas but only for a two-year period. Like Pearce and Venier (2005), they suggest that once relationships between small mammals and vegetation structure are identified, vegetation structural indices, rather than monitoring small mammal abundance, may serve as more efficient measures of the effects of silviculture on wildlife communities.

Conduct-Landscape Level Analyses

Lautenschlager and Sullivan (2002) reviewed the few landscape analyses that had been completed up to 2002 and concluded that “Canadian forests continue to regenerate after a combination of human- and natural-caused disturbances, but the escalating loss of conifers from these ecosystems is socially and ecologically troubling.” To determine whether herbicide reductions would contribute to further loss of conifers, Dacosta *et al.* (2011, this issue) conduct a landscape-level analysis of two forests in northeastern Ontario. Dacosta *et al.* (2011) also analyzed other indicators of sustainability identified in the forest management plans (FMPs) for these areas, such as maintaining forest unit area, harvest area and volume, pine component, preferred wildlife habitat, biodiversity, and old growth.

Dacosta *et al.*'s (2011) modelling exercise indicates that in FMPs with multiple competing objectives for wood supply and habitat supply, systematic herbicide reductions could decrease the total available volume of conifers and hardwoods as well as the habitat supply for some wildlife. The magnitude and type of habitat effects appear to depend on the species assessed. For example, constraints such as herbicide reduction that result in reduced harvest area could reduce the supply of habitat for species preferring recent disturbances such as moose, bears, and kestrels. Simulations also suggested that patch size and distribution changed on the simulated landscape with the frequency of small patches increasing as herbicide use was reduced. Thus, herbicide reduction can influence the spatial pattern of the landscape, an attribute that is important to some species of wildlife.

The results of these studies indicate that both forest composition and structure will be affected by FVM. Of greatest concern is the consistent prediction that there will be reductions in the conifer component within the studied forests. Successful conifer re-establishment is based on an interaction among conifer species, stocking and density, treatment efficacy, and site quality (Bell *et al.* 2011b). Unless resource managers apply FVM treatments that can successfully re-establish conifers at the stand level, a reduction in the conifer component at the landscape-level will likely continue.

Transfer Information

Information gained from all aspects of this exercise has been transferred to resource managers via field workshops, e-lecture series, Web sites, and one-on-one interactions. This combination of methods has ensured that many individuals across Canada are already aware of some or all of the information presented here.

Of these methods, the self-learning field workshops were probably unique. Resource managers are familiar with field workshops where experts are given the active role of presenting information about their research and participants assume a semi-passive role of listening and asking questions. Although the lecture series approach may work for some audiences, this passive audience approach is not an effective means for informing the public (Wyatt *et al.* 2011). In the self-learning field workshops both experts and participants had active roles. Project partners hosted two self-learning field

workshops in 2010. Participants included resource managers, members of local citizens' committees, academics, and students. The participants were divided into small groups of five to eight individuals and assigned the role of researchers. As such, they were requested to develop hypotheses and data collection methods, collect and summarize data, present results, and lead discussions about how or if their findings deviated from their hypotheses. Participants explored a diverse range of topics, including silvicultural effectiveness, wood quality, and cost of using motor-manual cutting, as well as, for example, the effects of forest vegetation management treatments on plant diversity, wood frog habitat, and soils. For each topic, experts guided the groups through the various stages. This approach provided a powerful learning experience for all involved and can easily be adapted to other situations/topics.

Summary

In summary, we hope that this collection of papers will provide forest resource managers with an updated, Canadian-based, state of knowledge on key issues relevant to forest vegetation management (FVM) in boreal and temperate forests. Although many issues are involved, three key issues are inter-related. Resources managers are required by law to maintain forest cover and other values within a sustainable or ecosystem management approach; this includes conifer-dominated stands. Second, conifer regeneration is typically slow to establish and readily out-competed by many fast-growing plant species that rapidly occupy harvested areas. Third, the use of FVM treatments, specifically herbicides, that can, within reasonable financial limits, control competitive species on publicly owned lands (which in Canada includes about 95% of the forested land area) is restricted or banned due to concerns about environmental effects. This is so despite many years of research failing to provide supporting evidence of negative effects under operational conditions. Until these issues are resolved, reductions of conifer occurrence and abundance will continue on the Canadian landscape.

To address these issues we recommend that resource managers conduct landscape-level sensitivity analyses on the use of alternative treatments to determine the ecological, social, and financial costs of meeting landscape-level objectives and negotiate with stakeholders on the choice of FVM treatments. For this to work, stakeholders involved in forest management will need to develop a basic understanding of the issues, including the autecology of forest plants, efficacy of FVM treatments, environmental concerns, conifer growth rates, economics, and social concerns. When interacting with stakeholders, we recommend the "self-guided approach to learning" as described above as an alternative to information sessions, presentations, or publications.

The key issues related to the use of FVM are discussed in the papers that follow, hopefully in a way that is useful to those involved in deciding the future direction of conifer management in Canadian forests.

Acknowledgements

Financial support for this series of papers was provided by the Agricultural Research Institute of Ontario, the Canadian Ecology Centre – Forestry Research Partnership, and Domtar Inc.

Study leads are indebted to Jim Baker (OMNR) for project advice and administration, Lisa Buse (OMNR) for reviewing and editing manuscripts and coordinating the peer review process, Michael Irvine (OMNR) for project advice, Matt Meade and John Pineau (CIF) for coordinating field workshops and CIF lecture series, and Sue Pickering (CEC-FRP) and Chris Hollstedt (FORREX) for administration. Special thanks are extended to the many authors and peer reviewers of the papers presented in this special issue of *The Forestry Chronicle*; without their efforts it would not have been possible.

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