A Guide to Opportunities

The Clearcut Silviculture System as Related to Vegetation Management

R. Whaley*
B. Polhill*

Index

Introduction 1
System Review 2
Vegetation Response to the Clearcut Silvicultural System 3
- Competitive Species 3
- Crop Species 5

Management Implications 6
- Treatment Timing and Methods 6

Summary 8
Appendix
- Species Listing 10

Affiliation

* Ministry of Natural Resources
Northwest Science & Technology
RR#1, 25th Sideroad
Thunder Bay, Ontario
P7C 4T9

Introduction

The Boreal Forest Region is dominated by both shade-intolerant and moderately shade-tolerant tree species including jack pine, trembling aspen and black spruce. These species are adapted to the environmental conditions which occur following large stand-replacing disturbances such as fire, windthrow, disease or insect infestation, all of which are common to the boreal forest.

The clearcut silvicultural system is a system of regenerating an even-aged forest stand in which new seedlings become established in fully exposed micro-environments after most or all of the trees have been removed. Regeneration can originate naturally or artificially (OMNR 1996). The clearcut system provides the biological requirements for the establishment of shade-intolerant pioneer tree species, thereby simulating the effects of natural stand-replacing disturbances. However, this system, while providing favourable environmental conditions for the regeneration of shade-intolerant tree species, also provides opportunities for competitive, non-crop species to invade a clearcut site. The successful regeneration of shade-intolerant tree species is therefore dependent upon the formulation and implementation of a vegetation management strategy which will minimize the adverse effects that competitive species may have on the crop trees.

Advantages of the clearcut system include:

- regeneration of highly desirable shade-intolerant tree species
- establishment of a well-stocked and well-spaced crop
- flexibility for improving wildlife habitat through creation of edge and provision of browse species
- production of high volume yields

This note briefly describes the harvest methods common to the clearcut silvicultural system, the vegetation responses to these methods and the role of vegetation management plans in the clearcut system.

Photo by W.D. Towill

System Review

The clearcut silvicultural system is comprised of:

- a harvesting component where all merchantable trees are removed, although a small number may be left as seed trees to provide a seed source for natural regeneration
- a renewal strategy which may consist of natural regeneration or treatments such as site preparation and planting or seeding
- tending treatments to maintain desired species composition and provide crop trees with space to grow

In Ontario, where 72 percent of the productive forest is located in the Boreal Forest Region, clearcut harvesting accounts for 61 percent of all harvesting (Figure 1). Five harvest methods are associated with the clearcut silvicultural system in Ontario.

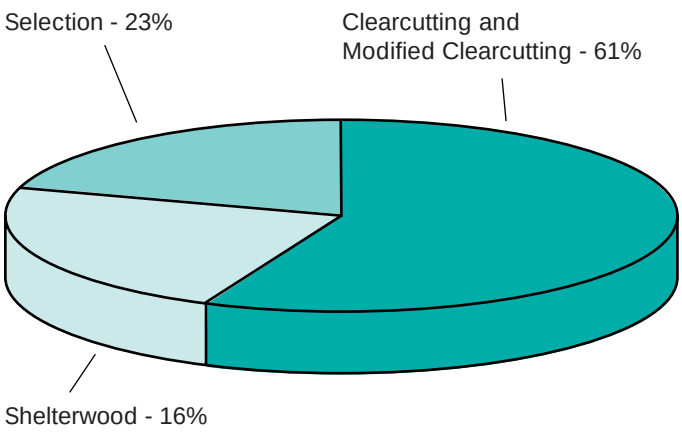

Figure 1:
Silvicultural systems used in Ontario: April 1, 1992 to March 31, 1993 (OMNR 1993).

1. Conventional: the harvested area is larger than two hectares and has an irregular pattern dictated by site conditions, topography, forest type, spatial distribution of age classes and wildlife concerns (Figure 2).
2. Patch: the harvested area is less than two hectares in size and has an irregular shape (Pulkki 1997). Patch cutting is commonly undertaken to protect wildlife or aesthetic values. It may be implemented as a two-cut system where half of the stand area is removed in the first cut and the remainder in the second cut.
3. Block: the harvested area is less than two hectares and has a regular (usually square) shape (Pulkki 1997). It may be implemented as a two-cut system where half of the stand area is removed in the first cut and the remainder in the second cut. Alternating harvested and standing blocks form a checkerboard pattern.
4. Strip: The strips can be rectangular or square, and are usually oriented at right angles to the prevailing wind to protect against windthrow and to enhance seed dispersal. Strip width is determined by the effective seeding distance of the standing desirable tree species (generally 40 to 80 metres [m]) and strip lengths vary from 180 to 300 m (Figure 3).

a) Alternate strip: harvested strips alternate with unharvested strips and both are usually cut in a ten year harvest period.

b) Progressive strip: adjacent strips are cut in a sequential order usually over a twenty year period. Strips are usually wider than 40 m.

5. Group and Single Seed-Tree: all trees are removed from an area except for a small number of seed-bearing trees (usually less than 25 trees per hectare). Trees are retained either singly or in small groups to provide seed for natural regeneration (Figure 4).

Figure 2:
Conventional clearcut harvest method.

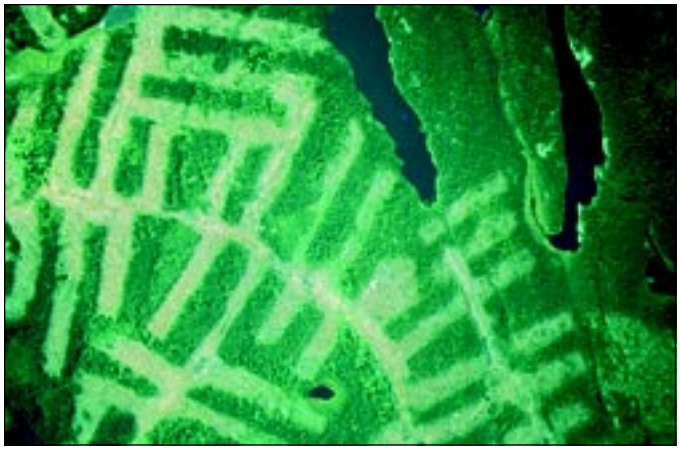

Figure 3:
Strip cut harvest method. (Photo by F. Kreikman)

Patch, block, strip and seed-tree cutting are frequently referred to as modified clearcut harvest methods. The species and site conditions commonly associated with each type of harvest method are listed in Table 1.

The advantages and limitations of the clearcut harvest method and its modifications are summarized in Table 2.

Vegetation Response to the Clearcut Silvicultural System

Major disturbances such as fire or clearcut harvesting remove all or most of the forest overstory and create environmental conditions very different from those in a mature forest stand. Margolis and Brand (1990) (based on a review of other studies) report increases in light intensity, soil temperature, soil moisture and nutrient availability following fire or clearcutting. These changes create conditions which promote the establishment of pioneer tree, shrub and herb species typical of the boreal forest. Revegetation of a disturbed site is influenced by the regeneration strategies of the crop and competitive species that are capable of re-establishing on the site. Strategies include vegetative propagation from roots and other plant parts, the availability of viable seeds in soil seed banks, and the opportunity for wind-borne seeds from adjacent uncut stands to germinate and become established on the site.

Competitive Species

On sites where the forest floor is undisturbed or moderately disturbed following logging, residual species which reproduce from shoot sprouts (e.g. mountain maple, alder, hazel, birch, willow, Labrador tea) or root suckers (e.g. blueberry, aspen, raspberry, willow) will increase their coverage of the forest floor. For these species, the level of increase is directly related to the degree of disturbance (Buse and Bell 1992). Seed bank species (e.g. dogwood, pin cherry, raspberry, blueberry) germinate from seeds buried in the forest floor and follow a similar pattern of establishment (Figure 5). Wind-borne seed species (e.g. fireweed, Canada blue-joint grass, birch, aspen, willow) have a greater colonization rate when there has been sufficient disturbance to create receptive seedbeds (Buse and Bell 1992).

Crop Species

Stand and site conditions influence the re-establishment of crop species after clearcut harvesting. Conifer-dominated upland sites in northwestern Ontario regenerate primarily to jack pine following harvest if jack pine is present in the pre-harvest stand (Ellis and Mattice 1974; Symons 1996; Bowling et al. 1997). When black spruce is present in the original stand, ingress of spruce is moderate to high and occurs over a longer period of time. Aspen regeneration is high when it is present in the pre-harvest stand, and, with jack pine, frequently overtops the spruce

Table 1:
Silviculture systems and where they are commonly applied.

Clearcut Harvest Method	Applicable Species	Applicable Site Conditions
Conventional	Shade intolerant species such as aspen, jack pine and red pine.	Suitable for all site and soil conditions although limitations to season of harvest and equipment may be required. On sites where stand conversion is the regeneration objective.
Patch, block or strip	Used in Ontario for black spruce, and in the northeastern U.S. for regenerating white birch (Safford 1983). This method has potential for regenerating jack pine–black spruce stands, white spruce–aspen mixedwood, and white pine–aspen mixedwood stands (Jeglum and Kennington 1993). Potential option for white pine or red pine (Chapeskie et al. 1989).	Shallow soils over bedrock; wet organic soils; deep moist outwash sands; boulder pavement or stony outwash are most common (Jeglum and Kennington 1993). . Use on other sites depends on levels of competition, economic considerations and accessibility (Jeglum and Kennington 1993).
Seed-tree	Group and single seed-tree systems have been used for white pine. Group seed-tree is an option for black spruce stands and can be combined with other systems such as strip cuts (Arnup et al. 1988).	Trees must be windfirm. Sites with low potential for non-crop competition are optimal. Often used on sites where planting is not an option (i.e. shallow soils, wet organic soils).

Table 2:
Advantages and limitations of the clearcut and modified clearcut harvest methods.

Advantages of Clearcut Harvest Methods	**Limitations of Clearcut Harvest Methods**
• Conducive to regenerating forests under even-aged management (Walstad *et al.* 1987). • Lends itself to the establishment of a well-stocked and well-spaced crop. • Increased light availability and higher soil temperatures which promote regeneration of shade-intolerant species (Galloway 1985; Davidson *et al.* 1988). • Provides highest volume yields. • Provides opportunities for improvement of the yield and quality of the new crop through the introduction of superior genotypes. • Regeneration of shrubs and herbs may provide a diverse source of food for wildlife such as moose (McNicol and Timmerman 1981). • Irregular cutover boundaries can increase the "edge-effect" important to wildlife species such as moose (Chapeski *et al.* 1989). • Harvesting layout and implementation is less complicated and more economical. • Harvesting operations are concentrated in one area over a short period of time so harvesting, transportation, regeneration and road-building costs are minimized (Walstad *et al.* 1987; B.C. Min. For. 1991). • Harvest and renewal operations are flexible enough to accommodate most equipment. • Removal of all or most trees enables broadcast herbicide application for vegetation management.	• Not aesthetically acceptable to many (Walstad *et al.* 1987; McGee 1992). • Seedlings may be susceptible to desiccation, frost damage, soil heaving, snow loading and increased soil surface temperatures (Lousier 1990; Hirasuka and Zalasky 1993). • Potential for erosion hazard on steep slopes (Robertson 1945). • Some sites may be exposed to degradation through excessive drying and flooding. • Increased amount of light and higher soil temperatures promote the reproduction of competing pioneer species. • May result in loss of winter shelter and cover for ungulates or a loss of nesting sites for waterfowl, grouse and cavity nesting birds. (Crouch 1983; Arnup *et al.* 1988; B.C. Min. For. 1991; McGee 1992). • Prolonged use of clearcutting dispersed with patches of standing forest may cause habitat fragmentation (McGee 1992).
Advantages of Modified Clearcut Harvest Methods	**Limitations of Modified Clearcut Harvest Methods**
• Promote natural regeneration (Jeglum and Kennington 1993). • Reduce the visual impact of conventional clearcutting (e.g. chevron (>) patterns along highways). • Suit local topography, drainage patterns and site conditions. • Provide some shelter for developing seedlings by moderating the microclimate (Walstad *et al.* 1987). • Reduce the amount of vegetative competition by increasing shade from leave strips and patches (Jeglum and Kennington 1993). • Provide habitat for cavity nesting birds by leaving nesting trees (B.C. Min. For. 1991).	• Roads must be maintained for a longer time to facilitate harvest of leave strips, blocks or patches. • Seed trees may be damaged by harvesting equipment. • Harvesting layout and implementation are more complicated and costly than for conventional clearcutting (Hynard 1988). • Windthrow can be a major problem for shallow-rooted species such as black spruce; therefore harvest of leave strips, blocks or patches may be reduced and the seed source in seed tree cuts may be eliminated (Hynard 1988; Jeglum and Kennington 1993). • There is no control over seedling distribution and spacing unless additional silvicultural treatments are implemented. • Regeneration success can be variable due to periodicity of seed production, seedbed availability, receptivity and distribution across the cutover, and animal predation of seed.

regeneration (Figure 6). Jeglum (1984) found that stands which are dominated by black spruce before harvest regenerate to intolerant hardwoods after disturbance.

Service (1997) found that balsam fir was the dominant crop species on northwestern Ontario post-harvest spruce–fir sites which had received no further silvicultural treatments. The lack of an adequate seed source and receptive seedbeds precluded high levels of black and white spruce regeneration. Black spruce was the primary regenerating species on lowland, organic sites (Bowling et al. 1997; Service 1997).

On hardwood-dominated mixedwood sites, aspen and balsam fir will form the next crop on untreated cutovers (Yang and Fry 1981; Symons 1996; Bowling et al. 1997). The presence of spruce in the new mixedwood stand depends on its presence in the pre-cut stand. Twenty-five years after harvesting, hardwood cutovers had converted to mixedwood stands with balsam fir as the conifer component (Yang and Fry 1981). Mixedwoods remained as mixedwoods for 30 years after harvesting.

Figure 4:
Single seed-tree harvest method. (Photo by W.D. Towill)

Management Implications

The clearcut silvicultural system is a flexible, even-aged system which can be modified on most ecosites to take advantage of natural regeneration opportunities, protect fragile sites or provide aesthetically pleasing views. Clearcutting is a recommended harvest method for all ecosites where the regeneration of pioneer species such as jack pine or aspen is the objective. Following harvest, competition levels from non-crop species vary greatly between ecosites. Generally, ecosites with coarse, dry soils will have low competition levels, as will mature, fully-

Figure 5:
Wild red raspberry (Baldwin and Sims 1989).

Figure 6:
Aspen overtopping spruce regeneration.

stocked conifer stands. In hardwood, mixedwood or conifer stands which are breaking up, the level of light which reaches the forest floor increases, and consequently the level of competition also increases dramatically. Resource managers can benefit from pre-harvest assessments to select the most suitable harvesting method and plan effective vegetation management control programs. Before applying any vegetation management treatment, however, it is important to consider the silvics of the target vegetation and how it relates to the treatments being considered.

Treatment Timing and Methods

Vegetation management plans for forest stand establishment include season of harvest, cut layout and design, site preparation, regeneration method and tending. The purpose of vegetation management treatments is to control the establishment of competitive species, reduce the size, vigour and numbers of these species to a level at which they have little or no effect on the crop trees, and to avoid a reduction in ecological diversity (Sutherland and Foreman 1995).

i) Harvest

Modified harvesting, such as strip cutting on sites where trembling aspen has the potential to outcompete conifer crop species, may reduce temperatures in the adjacent leave strips, thereby decreasing the extent of regeneration by suckering (Racey et al. 1989). Strip cutting and seed-tree cutting also provide opportunities for natural black spruce and jack pine regeneration to become established.

Season of harvest will affect the establishment of competitive non-crop species. Summer logging reduces aspen and green alder establishment, but stimulates the vegetative reproduction of Canada blue-joint grass, sedges, fireweed and pin cherry. Killing aspen with herbicides or girdling prior to logging, will also reduce aspen suckering.

Where aspen regeneration is desirable, clearcutting to promote full exposure to sunlight, or site preparation which results in disturbance of the humus layer, will enhance sucker production. Excessive disturbance of the forest floor, however, may damage the aspen root systems and reduce suckering potential.

ii) Site Preparation

Site preparation treatments in the clearcut system can consist of mechanical treatments (Figure 7), herbicide application (Figure 8), prescribed fire, or combinations of these. However, mechanical site preparation is the most common method. The positive effects of site preparation treatments on site and crop species are:

- increased soil temperature as a result of removing the vegetation that shades the soil or by reducing the thickness of the organic layer
- soil moisture conservation due to decreased transpirational losses through the removal and killing of competing vegetation
- enhanced nutrient availability for crop species due to the reduction of competing non-crop species (Sutherland and Foreman 1995)

The negative impacts of site preparation may include:

- increased susceptibility of crop trees to seasonal moisture stresses and frost heaving
- modification of soil surface and pore structure
- potential for development of high soil surface temperature and increased differences between day and night temperatures
- site degradation and reduced fertility following removal of organic layer
- promotion of vegetative sprouting and germination of seed bank non-crop species
- damage to advance growth of desirable crop species (Sutherland and Foreman 1995)

When site preparation removes only the surface vegetation and leaves the humus layer intact, the species composition on the post-treatment site will not be changed; only the height and cover of the competing vegetation will be reduced (e.g. winter shearing). Mechanical site preparation that exposes the mineral soil by removing the surface organic layer (e.g. spot scarification, deep blading), promotes the establishment of wind-borne and seed bank species, thereby resulting in a change in species composition on the treated area. Sprouting of the original on-site vegetation will depend on the presence of root systems that have remained in the soil after harvesting and site preparation (Sutherland and Foreman 1995).

In recent years, resource managers have combined mechanical site preparation methods with chemical and prescribed burning methods to obtain vegetation control. These treatments can be carried out simultaneously (i.e. mechanical with chemical site preparation), or they can be used consecutively (i.e. prescribed burning can follow or precede mechanical site preparation). Application of a combined mechanical/chemical site preparation treatment using a foliar-absorbed, translocated herbicide, is most effective if the herbicide application is delayed after mechanical treatment until regrowth has occurred. This will ensure that translocation of the herbicide to the roots of the competing plants has taken place (Bell 1991). Soil-active herbicides are most effective if applied after a mechanical treatment but before growth has begun. Simultaneous mechanical/chemical site preparation may have a negative impact on tree seedlings as a result of nutrient immobilization and an allelopathic effect on crop trees from decomposing plant residues (Bell 1991). Site preparation using prescribed burning may control sprouting and suckering in trembling aspen, willow, mountain maple and hazel by killing stems and roots (Racey et al. 1989). Canada blue-joint grass can be effectively controlled by the maintenance of good drainage on a cutover, since it does not readily invade dry sites (Racey et al. 1989). Site preparation during dry periods will also reduce aspen suckering.

iii) Regeneration Method

Under the clearcut silvicultural system, stand establishment may occur by natural or artificial means. Natural regeneration includes crop tree establishment by seeding, suckering, sprouting and layering; artificial regeneration involves the planting or di-

rect seeding of crop tree species. The selection of a regeneration method depends on numerous factors, including:

- availability of a seed source
- presence of advance growth
- availability of microsites
- site characteristics
- pre-harvest stand composition
- competition levels

Tree planting provides a resource manager with control over the spacing and distribution of the crop tree species, whereas seeding (natural or artificial) may require future spacing treatments to obtain a well-spaced stand.

Seeding success depends to a large degree on the adequate distribution of receptive seedbeds, and, in the case of natural seeding, on the presence of a nearby seed source. On mixedwood sites, smothering of seedbeds with hardwood litter may limit seeding success. In addition, the abundance and vigour of competitive species on these sites may preclude the establishment of crop trees from seed.

Advance growth consists of the young trees which have become established under the main canopy of trees either by seed or layering. In northwestern Ontario black and white spruce and balsam fir may occur as advance growth. Advance growth may contribute significantly to the regeneration objectives of a cutover area, particularly on lowland black spruce sites. On upland sites, advance growth is commonly used in combination with other regeneration methods such as planting or seeding.

iv) Tending

The purpose of tending treatments is to divert the resources of the site from the competing vegetation to the crop trees. Manual and mechanical tending methods, although more expensive than chemical methods, are selective in that they are applied only to vegetation that is competing directly with the crop trees (Figure 9). These treatments may have to be repeated one or two years after the initial treatment since many competing shrub species (e.g. alder, mountain maple, dogwood, hazel) will sprout vigorously after manual or mechanical cutting, forming a dense and competitive layer of vegetation (Buse and Bell 1992). However, scheduling cutting to coincide with periods of low carbohydrate reserves (i.e. the period in the spring immediately following shoot elongation and leaf-out) will reduce the growth of sprouts (Bell 1991). Other tending treatments include girdling of competitive species, either with or without the use of chemicals, and animal grazing. The use of cover crops and physical barriers to non-crop competition (e.g. mulch mats) are also alternative vegetation management tools.

The efficacy of chemical tending and site preparation treatments is influenced by the mode of action of the herbicide, susceptibility of plant species to various herbicides, and the proper timing of the application. In Ontario, most herbicide treatments for the release of conifers are carried out in late August or early September, when the likelihood of damage to the crop trees is reduced. Herbicides are commonly applied using aircraft or ground equipment. Public opposition to herbicide application, however, has fuelled research into developing alternative, chemical-free methods of vegetation management.

Figure 7:
Mechanical site preparation with drags.
(Photo by G. Racey)

Figure 8:
Site preparation by herbicide application.
(Photo by R. Maki)

Summary

There are few sites in northern Ontario where a clearcut silvicultural system will not be effective. However, consistent success requires a full awareness of the benefits and limitations of this system, a knowledge of specific site and stand conditions and a vegetation management strategy.

Vegetation management is an important component of the clearcut system. Harvesting methods may be modified to prevent sprouting or seeding of competitive non-crop species, or to promote the regeneration of desirable tree species. Site preparation, in addition to preparing favourable microsites for the establishment of crop species, is also used in the clearcut system as a method of controlling undesirable vegetation. The timing and method of the site preparation technique will depend on the soils and nutrient status of the cutover site, pre-harvest species composition, regeneration method and economic considerations. On nutrient-rich, productive sites, tending to release crop trees from competition may be an essential component of a vegetation management strategy. Chemical herbicides are commonly used to control non-crop species such as alder, raspberry and Canada blue-joint grass. The susceptibility of the target species will determine the timing of the application and the chemical to be used. Alternatives to chemical tending include manual and mechanical methods. However, regrowth of most common shrub species is rapid and tending treatments may need to be repeated.

Figure 9:
Motor manual tending for crop tree release.
(Photo by L. Godwin)

Literature Cited

Arnup, R.W., B.A. Campbell, R.P. Raper, M.F. Squires, K.D. Virgo, V.H. Wearn and R.G. White. 1988. A silvicultural guide for the spruce working group in Ontario. Ont. Min. Natur. Resour., For. Resour. Group, Sci. and Tech. Series Vol. 4. 100 pp.

Baldwin, K.A. and Sims, R.A. 1989. Field guide to the common forest plans in northwestern Ontario. Ont. Min. Natur. Resour., Toronto, ON. 344 pp.

B.C. Min. For. 1991. Silvicultural systems: their role in British Columbia's forest management. Silviculture Series. 42 pp.

Bell, W.F. 1991. Critical silvics of conifer crop species and selected competitive vegetation in northwestern Ontario. For. Can. Ont. Reg., Sault Ste. Marie, ON. and Ont. Min. Natur. Resour., Northwestern Ont. For. Tech. Dev. Unit, Thunder Bay, ON. COFRDA Rep 3310/NWOFTDU Tech. Rep. 19. 177 pp.

Bowling, C., G. Niznowski and M.L. Maley. 1997. Ingress of natural regeneration in plantations after tree-length harvest in northwestern Ontario. Ont. Min. Natur. Resour., Northwest Sci. & Technol., Thunder Bay, ON. TR 112. 23 pp. + Appendix.

Buse, L.J. and F.W. Bell. 1992. Critical silvics of selected crop and competitor species in northwestern Ontario. Ont. Min. Natur. Resour., Northwestern Ont. For. Tech. Dev. Unit, Thunder Bay, ON. 138 pp.

Chapeskie, D.J., D.F. Galley, J.R. Mihell, N.W. Quinn and H.H. Struik. 1989. A silvicultural guide for the white pine and red pine working groups in Ontario. Ont. Min. Natur. Resour., For. Resour. Group, Sci. and Tech. Series Vol. 6. 102 pp.

Crouch, G.L. 1983. Effects of commercial clearcutting of aspen on understory vegetation and wildlife habitat values in southwestern Colorado. USDA For. Serv., Rocky Mtn. For. and Range Exp. Sta. Res. Pap. RM-246. 8 pp.

Davidson, R.W., R.C. Atkins, R.D. Fry, G.D. Racey and D.H. Weingartner. 1988. A silvicultural guide for the poplar working group in Ontario. Ont. Min. Natur. Resour., For. Resour. Group, Sci. and Tech. Series Vol. 5. 67 pp.

Ellis, R.C. and C.R. Mattice. 1974. Stand development following pulpwood harvesting at the Experimental Lakes area in northwestern Ontario. Can. For. Serv., Great Lakes For. Res. Cent. Inf. Rep. No. O-X-207. 43 pp.

Galloway, R. 1985. A silvicultural guide to the jack pine working group. Ont. Min. Natur. Resour., Silv. Guide Series. 40 pp.

Hirasuka, Y. and H. Zalasky. 1993. Frost and other climate-related damage of forest trees in the prairie provinces. For. Can., NW Region Inf. Rep. NOR-X-331. 25 pp.

Hynard, P. 1988. Report on silvicultural systems in Ontario. Pp. 59–142 in Statement of Evidence Panel 10. v. I. Environmental Assessment Hearings. Thunder Bay, ON.

Jeglum, J.K. 1984. Strip cutting in shallow-soil upland black spruce near Nipigon, Ontario. IV: Seedling-seedbed relationships. Can. For. Serv., Great Lakes For. Res. Cent. Inf. Rep. O-X-359. 26 pp.

Jeglum, J.K. and D.J. Kennington. 1993. Strip clearcutting in black spruce: a guide for the practising forester. For. Can., Great Lakes For. Res. Cent. Rep. 102 pp.

Lousier, J.D. 1990. Impacts of forest harvesting and regeneration on forest sites. B.C. Min. For. Land Manage. Rep. No. 67. 92 pp.

Margolis, H. A. and D.G. Brand. 1990. An ecophysiological basis for understanding plantation establishment. Can. J. For. Res. 20:375–390.

McGee, C.E. 1992. The regeneration clearcut: good, bad or just ugly? Forest Farmer. October 1992. Pp. 6–9.

McNicol, J.G. and H.R. Timmerman. 1981. Effects of forestry practices on ungulate populations in the boreal mixedwood forest. Pp. 141–154 in Whitney, R.D. and K.M. McClain (eds.). Boreal mixedwood symposium. Can. For. Serv., Great Lakes For. Res. Cent. Symp. Proc. O-P-9. 278 pp.

OMNR. 1993. A Summary of silvicultural operations. Ont. Min. Natur. Resour., Silv. Inf. System. Unpublished Document.

OMNR. 1996. Forest management planning manual for Ontario's Crown forests. Ont. Min. Natur. Resour., Toronto, ON. Queen's Printer for Ontario. 452 pp.

Pulkki, R.E. 1997. Forest harvesting. Lakehead University, Thunder Bay, ON. 108 pp. + Appendix.

Racey, G.D., T.S. Whitfield and R.A. Sims. 1989. Northwestern Ontario forest ecosystem interpretations. Ont. Min. Natur. Resour., Northwestern Ont. For. Tech. Dev. Unit, Thunder Bay, ON. NWOFTDU Tech. Rep. No. 46. 90 pp.

Robertson, W.M. 1945. Some observations on silvicultural cutting methods. Can. Dep. Mines and Resour., Lands, Parks and For. Branch. Silv. Res. Note No. 75. 18 pp.

Safford, L.O. 1983. Silvicultural guide for paper birch in the Northeast (revised). USDA For. Serv. Res. Pap. NE-535. 29 pp.

Service, K.N. 1997. Successional pathways in spruce–fir stands after spruce budworm infestation. Ont. Min. Natur. Resour. Rep. 24 pp.

Sutherland, B.J. and F.F. Foreman. 1995. Guide to the use of mechanical site preparation equipment in northwestern Ontario. Can. For. Serv., Sault Ste. Marie, ON. NODA/NFP Project 4113. 186 pp.

Symons, E. 1996. Natural regeneration of hardwood and softwood tree species following full-tree harvesting in northwestern Ontario. Natur. Resour. Can., Can. For. Serv., Great Lakes For. Cent., NODA/NFP Tech. Rep. TR-22. 16 pp.

Walstad, J.D., M. Newton and D.H. Gjerstad. 1987. Overview of vegetation management alternatives. Pp. 157–200 in Walstad, J.D. and P.J. Kuch (eds.). Forest vegetation management for conifer production. John Wiley & Sons Inc., New York, NY. 523 pp.

Yang, R.C. and R.D. Fry. 1981. Natural succession following harvesting in the boreal mixedwood forest. Pp. 65–77 in Whitney, R.D. and K.M. McClain (eds.). Boreal mixedwood symposium. Dept. Environ., Can. For. Serv., Great Lakes For. Res. Cent. COJFRC Symp. Proc. O-P-9. 278 pp.

Appendix

Species Listing

Common Name	Scientific Name
alder	*Alnus* spp.
green alder	*Alnus crispa* (Ait.) Pursh
aspen	*Populus* spp.
balsam fir	*Abies balsamea* (L.) Mill.
beaked hazel	*Corylus cornuta* Marsh.
black spruce	*Picea mariana* (Mill.) B.S.P.
blueberry	*Vaccinium* spp.
Canada blue-joint grass	*Calamagrostis canadensis* (Michx.) Beauv.
dogwood	*Cornus* spp.
fireweed	*Epilobium angustifolium* L.
jack pine	*Pinus banksiana* Lamb.
Labrador tea	*Ledum groenlandicum* Oeder
mountain maple	*Acer spicatum* Lamb.
pin cherry	*Prunus pensylvanica* L. fil.
raspberry	*Rubus* spp.
red pine	*Pinus resinosa* Ait.
sedge	*Carex* spp.
trembling aspen	*Populus tremuloides* Michx.
white birch	*Betula papyrifera* Marsh.
white pine	*Pinus strobus* L.
white spruce	*Picea glauca* (Moench) A. Voss
willow	*Salix* spp.

Acknowledgments

The authors wish to thank the following individuals for their valuable contributions to the production of this note:

- Art Groot
  Research Scientist, Canadian Forest Service
- Matsy Kenney
  OMNR, Northwest Science & Technology
- Reino Pulkki
  Lakehead University, Forestry Department

Finally, the authors thank Phil Elkie, Bob White and Ron Waito for their editorial review, and Ruth Berzel for publication production.

Disclaimer

The views, conclusions and recommendations are those of the authors and should not be construed as either policy or endorsement by Natural Resources Canada, Canadian Forest Service or the Ontario Ministry of Natural Resources.

This document should be cited as:

Whaley, R. and B. Polhill. 1998. The clearcut silvicultural system as related to vegetation management. Northwest Sci. & Technol. Technical Note TN–41, in Bell, F.W., M. McLaughlan and J. Kerley (compilers). Vegetation Management Alternatives - A Guide to Opportunities. Ont. Min. Natur. Resour., Thunder Bay, Ont.

5075
(2.2k P.R., 98 03 23)
ISSN 1201-9348