Regional-Specific Algorithmic Stand Density Management Diagram for Black Spruce

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ABSTRACT. *A regional-specific algorithmic stand density management diagram was developed for managed upland black spruce (Picea mariana* [Mill.] B.S.P.*) stands applicable to Newfoundland, New Brunswick, Quebec, and Ontario. Specifically, the IBM-compatible PC-based algorithm (1) graphically illustrates site-specific size-density trajectories for 8 user-specified initial density regimes, (2) calculates and subsequently tabulates periodic yield estimates from 5–50 yr by 5 yr intervals for mean dominant height, density, mean volume, total volume, total merchantable volume, quadratic mean diameter, and basal area, (3) given (2), graphically illustrates empirically derived yield production curves for total merchantable volume per hectare and number of stems per cubic meter with user-specified operability criteria superimposed, and (4) given (3), calculates and subsequently tabulates the minimum time required to attain operability status. The utility of the algorithm is demonstrated within the context of determining site-specific initial densities required to attain user-specified operability criteria. Procedures for acquiring the executable version via the Internet are also included. North. J. Appl. For. 15(2):94–97.*

Plantation establishment is one of the principal forest improvement practices employed in the management of black spruce (*Picea mariana* [Mill.] B.S.P.) throughout the central and eastern portions of the Canadian Boreal Forest Region (Anonymous 1996). Consequently, development of objective procedures for determining site-specific initial density regimes by management objective is a basic prerequisite to rational density management. Accordingly, an algorithmic stand density management diagram (SDMD) was developed for use in stand-level management planning (Newton 1997a).[1]

Although the underlying database used to construct the SDMD was derived from plantations established in Newfoundland, New Brunswick, and Ontario, the algorithmic version was limited to insular Newfoundland given the regional-specificity of the site index function used. Thus the purpose of this note is to present a regional-specific expanded version of the algorithm, applicable to Newfoundland, New Brunswick, Quebec, and Ontario. In addition, an operability module is included for determining site-specific initial densities required to attain user-specified operability criteria, thereby facilitating the delineation of the initial density regime for which the time to operability status is minimized. Operable or harvestable Boreal stands are commonly defined by threshold indices of usable fiber per unit area (merchantable volume per hectare) and piece size (stems per cubic meter). Consequently, minimizing the time to operability status is a primary management goal.

Description of the Algorithm

Similar to the algorithmic version of the SDMD previously developed for managed black spruce stands (Newton 1997a), the algorithm was developed for use on IBM (International Business Machines Corporation) or equivalent microcomputers. Specifically, the algorithm was written in Lahey FORTRAN[2] (F77L-EM/32, Version 5.20, Lahey Computer Systems Corporation) and employed a number of graphical subroutines developed by Heartland Software (HGRAPH, Version 5.00, Heartland Software Corporation) The executable version of the algorithm, denoted *SDMDMIG.EXE* (Stand Density Management Diagram for Managed stands—Interactive—Generalized—EXEcutable version), requires an (1) Intel (Intel Corporation) 80486DX or equivalent microprocessor operating under MS-DOS (MicroSoft's Disk Operating System, Version 6.0 or equiva-

[1] Refer to Newton (1997b) for a complete review of the underlying concepts, historical development, and applications of SDMDs in forest management.

[2] Complies with the FORTRAN (FORmula TRANslation) 77 standard (American National Standards Institute 1978).

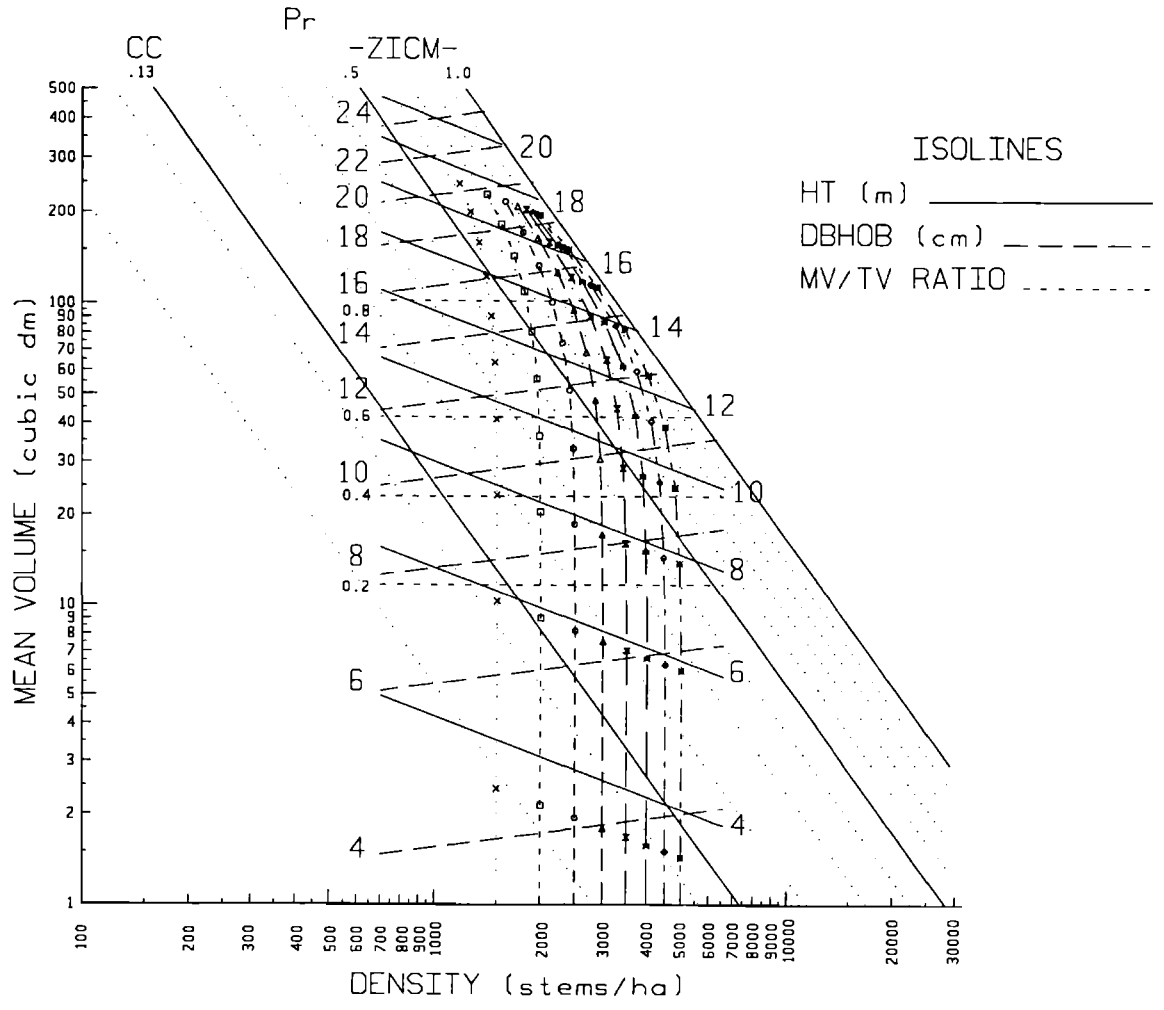

Figure 1. Sample graphical output generated employing the *SDMDMIG.EXE* algorithm (*n.*, color omitted). Stand density management diagram for managed black spruce stands graphically illustrating: (1) approximate crown closure line (CC) at a relative density (Pr) of 0.13; (2) lower limit of the zone of imminent competition-mortality (ZICM) at Pr = 0.50; (3) self-thinning rule at Pr = 1.0; (4) isolines for mean dominant height (HT), quadratic mean diameter (DBHOB) and merchantability ratio (MV/TV); and (5) expected size-density trajectories with 5 yr interval denotations for eight specified initial density regimes. Note, identical symbol and line types are used in both Figures 1 and 2 to denote equivalent initial density regimes. Input parameters employed: (1) regional code = 4 for Ontario; (2) site index = 18 m at 50 yr total age (Payandeh and Wang 1995); (3) initial density regime = 1500 stems/ha; (4) density interval between regimes = 500 stems/ha; and (5) operability criteria = 200 m^3/ha and 10 stems/m^3.

lent, Microsoft Corporation), and (2) a VGA (Video Graphics Adapter) screen device. Alternatively, the algorithm can be executed at the MS-DOS prompt within Windows 95 (Microsoft Corporation). Following program execution (i.e., typing ***SDMDMIG*** at the MS-DOS prompt), users are requested to interactively enter the following parameters: (1) regional-specific code for one of the four regions (i.e., numerals 1, 2, 3, and 4 for Newfoundland, New Brunswick, Quebec, and Ontario, respectively); (2) regional-specific site index based on functions developed by Newton (1992; Newfoundland), Ker and Bowling (1991; New Brunswick), Prégent et al. (1996; Quebec), and Payandeh and Wang (1995; Ontario); (3) initial planting density (stems/ha); (4) interval between planting densities (stems/ha); and (5) operability criteria expressed as minimum total merchantable volume per hectare and maximum number of stems per cubic meter. Site-specific size-density trajectories for the user-specified initial density regimes from 5 to 50 yr are graphically superimposed on the SDMD (e.g., Figure 1).

Resultant yield estimates are calculated by 5 yr intervals for each initial density condition and tabulated within an output data file denoted YESTM.DAT. Specifically, the data file consists of periodic yield estimates for mean dominant height (m), density (stems/ha), mean volume (dm^3), total volume (dm^3/ha), total merchantable volume (dm^3/ha), quadratic mean diameter (cm), and basal area (m^2/ha). Empirically derived yield production curves for total merchantable volume per hectare and number of stems per cubic meter with user-specified operability criteria superimposed are also graphically illustrated (e.g., Figure 2). Furthermore, minimum times required to attain each user-specified operability criterion is estimated through linear interpolation employing

[3] Note, these files are in compressed format [PKZIP (PKWARE Corporation) files] and hence require decompression before program execution. Users can obtain the utility program PKUNZIP.EXE from *http://www.pkware.com* (PKWARE Corporation, USA) and subsequently expand the compressed files by typing ***PKUNZIP sdmdmig.zip*** at the MS-DOS prompt.

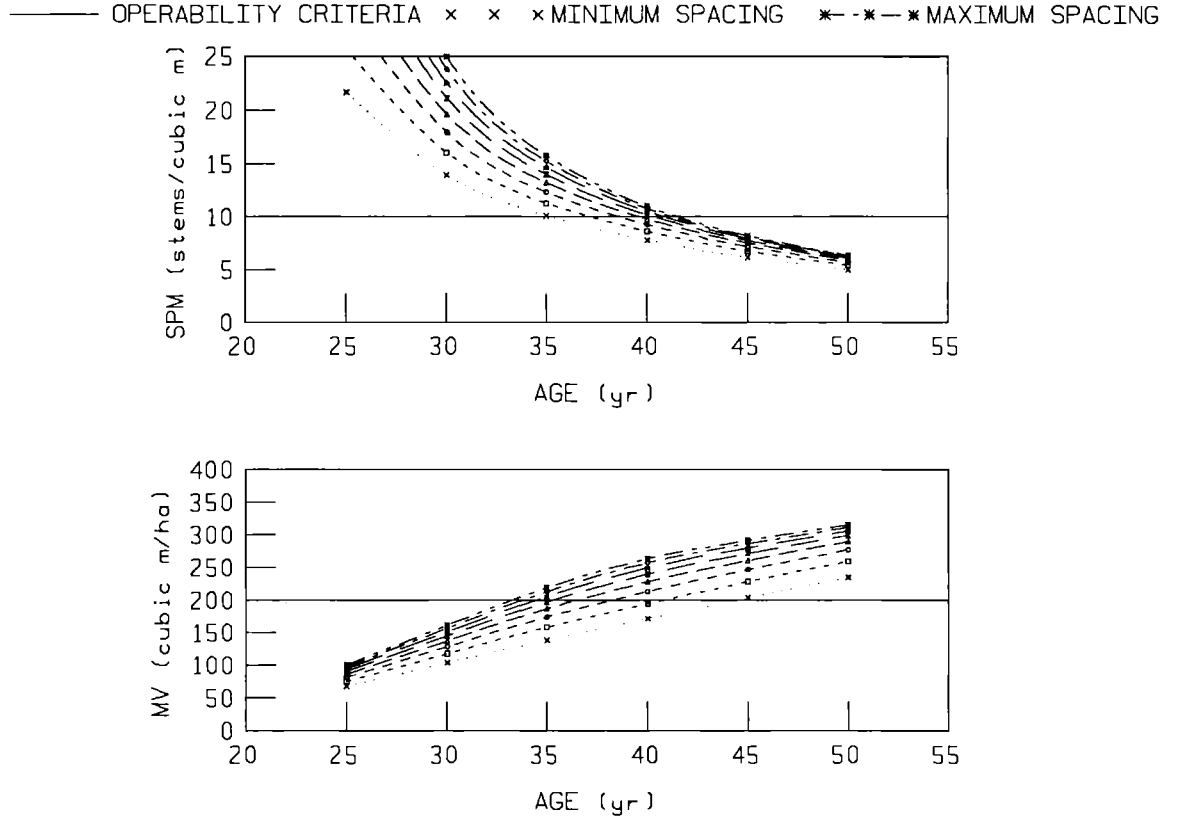

Figure 2. Sample graphical output generated employing the *SDMDMIG.EXE* algorithm (*n.*, color omitted). Empirically derived yield production curves for total merchantable volume per hectare (MV) and stems per cubic metre (SPM) with specified operability criteria superimposed (horizontal solid line). Note, identical symbol and line types are used in both Figures 1 and 2 to denote equivalent initial density regimes. Input parameters employed: (1) regional code = 4 for Ontario; (2) site index = 18 m at 50 yr total age (Payandeh and Wang 1995); (3) initial density regime = 1500 stems/ha; (4) density interval between regimes = 500 stems/ha; and (5) operability criteria = 200 m^3/ha and 10 stems/m^3.

the yield production curves and tabulated within the output data file (e.g., Table 1). Consequently, users can graphically determine the initial density which will attain operability status in the least amount of time. For example, based on operability targets of 200 m^3/ha and 10 stems/m^3 and given a range of possible plantation densities (1500 to 5000 by 500 stems/ha intervals), the diagram indicates that good quality upland black spruce sites situated in Boreal Ontario should be planted at a density of 2500 stems/ha in order to minimize the time to operability status (e.g., Table 1). Complete operating instructions including references, user notes, input requirements, and limitations are given upon program execution.

The executable version including the required graphical subroutines may be obtained through an anonymous FTP (File Transfer Protocol) server: *ftp.glfc.forestry.ca*. Simply (1) FTP to the server by typing ***ftp ftp.glfc.forestry.ca***; (2) enter ***anonymous*** following the name request; (3) enter your Internet e-mail address following the password request (e.g , *pnewton@nrcan.gc.ca*); (4) change the directory by typing ***cd pub/pnewton/outgoing/*** at the FTP prompt (e.g., ftp>), (5) set file type to binary by typing ***binary*** at the FTP prompt, (6) type ***get sdmdmig.zip*** at the FTP prompt and obtain the requested files[3]; and (7) exit the server by typing ***bye*** at the FTP prompt.

Table 1. Sample operability analysis generated employing the *SDMDMIG.EXE* algorithm (YESTM.DAT) (tabular listing of yield estimates by initial density regime omitted). Input parameters for sample run: (1) regional code = 4 for Ontario; (2) site index = 18 m at 50 yr total age (Payandeh and Wang 1995); (3) initial density regime = 1500 stems/ha; (4) density interval between regimes = 500 stems/ha; and (5) operability criteria = 200 m^3/ha and 10 stems/m^3.

Initial density (stems/ha)	Minimum time to attained merchantable volume per ha criterion (yr)	Minimum time to attained number of trees per cubic meter criterion (yr)	Minimum time to operability status[a] (yr)
1500	44.4	35.2	44.4
2000	40.8	37.4	40.8
2500	38.3	38.8	→38.8
3000	36.6	39.7	39.7
3500	35.3	40.4	40.4
4000	34.5	41.0	41.0
4500	33.9	41.4	41.4
5000	33.4	41.8	41.8

[a] Arrow denotes the minimum time to operability which is conditional on the user-specified operability criteria used.

Literature Cited

AMERICAN NATIONAL STANDARDS INSTITUTE. 1978. FORTRAN standard. Publ. X3.9.

ANONYMOUS. 1996. Compendium of Canadian forestry statistics 1995. Government of Canada, Dep. of Natur. Resour., Can. For. Serv., National For. Database Prog., Ottawa, Ontario, Canada.

KER, M.F., AND C. BOWLING. 1991. Polymorphic site index equations for four New Brunswick softwood species. Can. J. For. Res. 21:728–732.

NEWTON, P.F. 1992. Base-age invariant polymorphic site index curves for black spruce and balsam fir within central insular Newfoundland. North. J. Appl. For. 9:18–22.

NEWTON, P F 1997a Algorithmic versions of black spruce stand density management diagrams. For. Chron. 73:257–265.

NEWTON, P.F. 1997b. Stand density management diagrams: Review of their development and utility in stand-level management planning. For. Ecol. Manage. 98:251–265.

PAYANDEH, B., AND Y. WANG. 1995. Comparison of the modified Weibull and Richards growth function for developing site index equations. New For. 9:147–155.

PREGÉNT, G., V. BERTRAND, AND L. CHARETTE. 1996. Tables préliminaires de rendement pour les plantations d'Épinette noire au Québec. Gouvernement du Québec, Ministère des Ressources naturelles, Direction de la recherche forestiere. Memoirè de recherche forestière No. 118.