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Development of Stand Density Management Diagrams for Eastern Spruce - Balsam Fir Forests of the Acadian Forest Region: Progress Report for 2002-2003

Prepared for the Fundy Model Forest by:

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ABSTRACT

One of the most effective methods of planning stand density management in even-aged stands is through the use of stand density management diagrams (SDMD's). SDMD's are an average stand level model that graphically illustrate the temporal relationships between yield, density, and morality at various stages of stand development. Since these diagrams allow the resource manager or landowner to develop potential crop plans through time for both timber and non-timber values, this silvicultural tool is extremely useful in promoting sustainable forest management.

In 1999, a group of partners of the Fundy Model Forest discussed the potential and possibility of developing SDMD's for the eastern spruce - balsam fir forests of the Acadian Forest Region after attending an Extension course on the subject at the Maritime Forest Ranger School. By the end of Phase II of the Fundy Model Forest, the three following SDMD's were developed with supporting software from the Ontario Ministry of Natural Resources: 1) balsam fir (*Abies balsamea*), 2) spruce - balsam fir as a bi-species model, and 3) spruce, red (*Picea rubens*) and black (*P. mariana*). The purpose of this report is to document the progress of the project over the last three years, and 2) report on the project's activities for the 2002-2003 fiscal year. The report provides a summary of the methodologies used in the development of the SDMD's and refinement of the existing supporting software, a discussion of the results, an accounting of expenditures, a listing of expenditures, and concluding remarks on present achievements and future direction.

Key Words: Acadian Forest Region, eastern spruce - balsam fir forests, Fundy Model Forest, software, stand density management diagrams.

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ACKNOWLEDGEMENTS

I would like to acknowledge the support and encouragement of my other two committee members, Mr. Rolland Gagnon and Mr. Jason Knox for the development of stand density management diagrams for the eastern spruce - balsam fir forests of the Acadian Forest Region. Deep appreciation is extend to Dr. Margaret Penner and Mr. Murray Woods for their constant patience to my many questions and their individual skills of making stand density management diagrams a reality. Numerous individuals from various organization also made the stand density management diagrams a reality by allowing the SDMD's Development Team access to their data bases. The assistance from Dr. Fan-Rui Meng, Dr. Tony Zhang, and Dr. Jun Yang to the project is also appreciated. I also thank the following for editorial review of this report: Mr. Dean Toole, Dr. Charles Bourque, Dr. Fan-Rui Meng, and Mr. Girvan Harrison. Lastly, I thank the staff of the Fundy Model Forest for recognising the need for the development of such tools and providing an environment for a cooperative research project to prosper.

D.E.S.

INTRODUCTION

Eastern spruce – balsam fir (*Abies balsamea*) stands form a dominant forest cover type in the Acadian Forest Region. The spruce component of these stands may consist of red (*Picea rubens*), black (*P. mariana*) and /or white spruce (*P. glauca*). Often the initial stand density of these forest cover types requires intensive forest management prescriptions (thinning) to obtain the desired timber and non-timber products. One of the most effective methods of planning stand density management in these even-aged stands is through the use of stand density management diagrams (SDMD's). SDMD's are average stand-level models that graphically illustrate the temporal relationships between yield, density, and mortality at various stages of stand development (Woods 1998, Farnden 2002). Since these diagrams allow the resource manager or user to develop potential crop plans through time for timber and non-timber values, this silvicultural tool is extremely useful in promoting sustainable forest management.

Recognizing the need for stand density management tools, the Fundy Model Forest has developed the following three SDMD's as a co-operative project: 1) balsam fir (Figure 3), 2) spruce – balsam fir , and 3) spruce (red and black). As a co-operative venture the SDMD's were incorporated into existing software that was developed by the Ontario Ministry of Natural Resources. The purpose of this report is to document the progress of the project over the last three years, and 2) report on the project's activities for the 2002-2003 fiscal year. The report provides a summary of the methodologies used in the development of the SDMD's and refinement of the existing supporting software, a discussion of the results, an accounting of expenditures, a listing of expenditures, and concluding remarks on present achievements and future direction.

METHODOLOGIES

PAST ACTIVITIES

The Maritime Provinces have had an active pre-commercial thinning program in young stands of softwoods and hardwoods (Murray and Cameron 1987). More recently, commercial thinning prescriptions in semi-mature and mature stands are gaining interest in forestry operations (Canadian Woodlands Forum 1998). A fundamental management decision is decide when a thinning prescription should occur in the development of a stand. SDMD's allow the users to determine whether the stand has reached the stage of imminent mortality and require a thinning prescription to reduce lost of stand volume from natural competition. At the initiation of the Canadian Forest Service, several Continuing Forest Education courses were conducted at the Maritime Forest Ranger School. After an initial SDMD course in 1999, some of the participates form a group to develop SDMD's for the eastern spruce - balsam fir forests of Acadia Forest Region as a cooperative project through the Fundy Model Forest.

WORKSHOP

On 14th and 15th of May 2002, a workshop was conducted by the Fundy Model Forest on the development of the SDMD's for the Acadian Forest Region at the Maritime Forest Ranger School, Fredericton, New Brunswick. The primary objective of the workshop was to acquaint potential users of the recently developed balsam fir SDMD and supporting software. A secondary objective of the workshop was to obtain feedback from the potential users for any necessary improvements to the software for operational use. The two-day workshop was developed and conducted under contract by Dr. Margaret Penner and Mr. Murray Woods of Forest Analysis Ltd., Huntsville, Ontario. Over twenty people from across eastern North America attended this international workshop. This international workshop has allowed the Fundy Model Forest to develop, assess, demonstrate and transfer technology, tools, methods, and processes of stand density management for sustainable forest and ecosystem-based management beyond the usual sphere of influence. It has also provided the Fundy Model Forest with the opportunity to provide information, education, training, and professional development to forest managers and woodlot owners. A two-page assessment form was developed by Forest Analysis Ltd. and passed out to all

participates at the end of the workshop. Dr. Tony Zhang from Forintek Canada Corp. Ltd. was the guest speaker, and presented two lectures on current wood quality results and issues revolving around plantations and thinning prescriptions. He also included current work on developing a diameter distribution, wood product, and economic modules for the black spruce SDMD's.

SURVEY

In late November and early December, a survey was sent to all participates of the May 2002 workshop; past participates of SDMD courses held at the Maritime Forest Ranger School, and other individuals interested in the development of SDMD. The return rate for the survey was approximately 10 to 15 . The top five choices for refinement of the existing software were:

1) development of a spruce (red / black) stand density management diagram;
2) incorporation of the spruce (red / black) stand density management diagram into the existing support software;
3) refinement of the existing software by including the following features:
    a) clear-all button,
    b) thin every "X' years option, and
    c) modify excel input screen;
4) development of size-density trajectories (mortality curves) for each SDMD created for balsam fir, spruce - balsam fir, and spruce stands; and
5) comparison of balsam fir growth and yield from the Green River spacing data to the data that was to used develop the New Brunswick balsam fir SDMD.

Although interest was expressed by some participates for the addition of forest products and economics modules into the current SDMD's, Dr. Tony Zhang felt that such studies may be outside the scopeof this project, as Forintek Canada Corp. Ltd. has currently four PhD candidates and two Post Doctoral Fellows working in this area for black spruce. The development of a diameter distribution module to the existing SDMD software was the next most requested addition identified from the survey.

DEVELOPMENT AND COMPARISONS OF ADDITIONAL SDMD's

Spruce SDMD

The development of spruce SDMD and spruce - balsam fir SDMD followed the same methodology that was used construction of the balsam fir SDMD (Penner *et al.* 2002).

Green River Data Set

The following model are used to estimate maximum density line and self-thinning coefficient:

$Ln(V_m) = a + b\ ln(N)$

Where V_m = average tree volume of stand ($m^3\ tree^{-1}$), N = stand density (stems ha^{-1})

To test if the Green River data is different from the other data in New Brunswick, the following hypothesis was designed:

Ho1: Maximum density line of Green River stands are different from the main data set.
Ho2: The self-thinning coefficient are different between the two data sets.

$Ln(V_m) = a + ka\ Gr + b\ln(N) + Kb\ G_r\ ln(N)$

Where G_r =1 if data source from Green River, 0 for other source, K_a and K_b are parameters.

The resulting volume-density diagram is shown in Figure 1. Stands with no thinning prescriptions were labeled as control = 1. Control = 0 are stands where thinning treatments were conducted . Initial analysis indicates that some stands are far below self-thinning line, and thus the data was mislabeled and excluded in the further analysis. Initial analysis indicate that there are stands in New Brunswick PSP with lower density that are begining to break-up or deteriorated (Figure 1). First model analysis excluded those stands in the process of break-up and it had the following equation:

1Ln(Vm) = A+Ka*GR + B*Ln(N)+Kb*Gr*Ln(N)

Results indicate that maximum density line of Green River stands are not significantly different from the other data. The self-thinning coefficient, t-value is at boundary and is marginally

significant in Green River data compare with New Brunswick data. Given that the Green River data sets still have more dense stands compare with the rest of New Brunswick datas, we can concluded that both maximum density line and self-thinning coefficients are not significantly different from the rest of data.

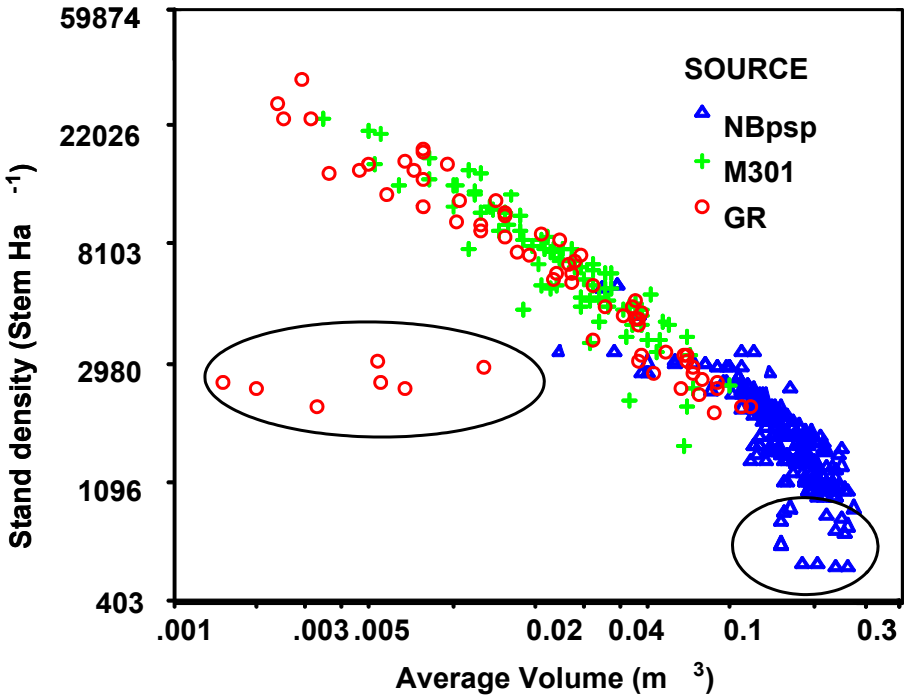

Figure 1 . Volume-density diagram used in the Green River data analysis.

DISCUSSION OF RESULTS

PRESENT DEVELOPMENTS

At the end of Phase II, the SDMD project has met the original objectives by producing another set of forest tools for stand density management (Figures 1 to 4). The success of the project is attributed to the efforts of many individuals from various organizations. First, the development of SDMD's for the eastern spruce - balsam fir forests of the Acadian Forest Region would not have been possible without the past and current silvicultural efforts of researchers and resource mangers alike. The data sets often represent the career spans of several researchers involved in long-term research projects. The generosity of the current data owners or "keepers" for the use of these data sets is much appreciated by the SDMD Committee. Dr. Margaret Penner has provided the necessary biostatistical skills required for the development and production of SDMD's. Instead of incurring the costs of developing supporting software, a cooperative agreement was made with Mr. Murray Woods to use the software that was developed by the Ontario Ministry of Natural Resources. In return, the Ontario Ministry of Natural Resources has received improvements to the software from work on the eastern spruce - balsam fir SDMD's. Such an agreement also benefits the potential users, as the various SDMD's are contained in one software package. Interactive supporting software has been found to be critical for the adoption and use of SDMD's by resource managers and field foresters (Woods 1997). Instruction on the development of SDMD's and the supporting software by Dr. Margaret Penner and Mr. Murray Woods allowed the Fundy Model Forest to provide information, education, training, and professional development for researchers, forest managers and woodlot owners from across eastern North America (Penner and Woods 2002). The workshop has also assisted in the development, assessment, demonstration, and technology transfer of SDMD's as a stand density management tool for sustainable forest and ecosystem management. Response from the potential users of the workshop has allowed the refinement of the software to a user's perspective rather than just a researcher's viewpoint. However, the resulting software is a useful tool for both field operations and research. The results of this project have both a sound scientific basis and the input from potential users.

At the workshop, one of the participants identified the possibility that regional variations of the SDMD's may exist in New Brunswick. The participate felt that the Green River area of New Brunswick was more productive for balsam fir growth and development than the current SDMD's projected. Data from the Green River balsam fir spacing trial (Ker 1987) was used to test whether there were significant differences between growth in the Green River area and the data used to develop the balsam fir SDMD. Dr. Fan-Rui Meng (Faculty of Forestry and Environmental Management, UNB) concluded there were no significant differences between the two data sets after using linear and non-linear regression techniques; and concluded as a result that the existing SDMD's can be adequately used for balsam fir stands in the Green River area (Fan-Rui Meng, Per. Comm. UNB. 2003). When the extreme values from each dataset were removed , no significant differences were detected for growth and yield. Extreme values for the Green River balsam fir spacing trial were plots that exhibit height growth stagnation from high stem densities. A few of the plots that provided the data for the development of SDMD's were extremely understocked for optimum fibre growth. Such plots did not exist for the data of the Green River balsam fir spacing trial. The data from the Green River balsam fir spacing trial should be incorporated into the existing SDMD's when mortality curves are developed (see next section).

FUTURE DEVELOPMENTS

Farnden (2002) groups SDMD's into four classifications of complexity depending on available data and intended use of the resulting diagram. The simplest SDMD's provide elementary guidance for thinning prescriptions and planting densities by containing only the basic boundary lines describing the self-thinning zone and crown closure lines. Such SDMD's are used to determine whether a specific stand should be thinned. By including sets of iso-lines representing top height and a measurement of a size parameter (average tree volume, basal area, or diameter), a second level of complexity is added to the resulting SDMD. A time element is added to the SDMD's with the addition of height isolines in association with height/age curves. The SDMD's developed for eastern spruce - balsam fir forests by the Fundy Model Forest are in this complexity classification, as are most of the SDMD's developed to date (Farnden 2002).

Such SDMD's, allow the user to predict the time required for a specific low thinning intensity to reach a desire average piece size. They also allow relative growth comparisons between different spacings or thinning intensities on different site indices.

With the addition of size-density trajectories (mortality curves), the SDMD's reach the third level of complexity of development. According to Farnden (2002) these lines added considerably more precision to predictions and perhaps accuracy to growth and mortality projects in the Zone of Imminent Mortality. The datasets used for the development of balsam fir SDMD's for the Acadian Forest Region have the quantity and quality of information for the production of size-density trajectories (mortality curves). It is not certain whether such information exists for the development of these curves for spruce - balsam fir and spruce SDMD's. However, the next logical step in the development of SDMD's for the eastern spruce - balsam fir forests (Acadian Forest Region) would be the production of mortality curves.

The fourth level of complexity for SDMD's have increased capabilities because of the inclusion of other parameters and additional axes to the diagram. The addition of forest products and an economics module into the current SDMD's would be an example of a fourth level of complexity. According to Farnden (2002), such developments in SDMD's have not been reached in an operational sense, and thus such activity would be beyond the usual scope of applied research activities for the Fundy Model Forest.

Future emphasis on SDMD's developed for the eastern spruce - balsam fir forests of the Acadian Forest Region should also include additional technology transfer efforts to partners of the Fundy Model Forest and other interested parties. The past workshop can serve as an excellent base to develop other mini workshops at different locations across the Fundy Model Forest. Such mini workshops would be an effective way to transfer this tool to other partners of the Fundy Model Forest. A planned poster at the side event for the World Forestry Congress by the Fundy Model Forest should provide additional exposure of the project to potential users. Resource Managers from the Newfoundland Forest Service have expressed an interest in the development of a SDMD for balsam fir based on participation at the workshop and results from this project. Future activities of the SDMD Development Team should explore the possibility of a collaborative project that networks the three model forests in Atlantic Canada (Fundy Model Forest, Nova Forest Alliance Model Forest, and Western Newfoundland Model Forest). Such an

increased marketing effort should increase the testing and additional refinement of existing SDMD's and supporting software.

In summary, the development and success of the SDMD's Project of the Fundy Model Forest has largely been accomplished by cooperation of many individuals at both the research and user level through networking activities by many organizations. Such a cooperative effort should be maintained in future development of SDMD's.

EXPENDITURES

Past and current project funding are shown in Tables 1 and 2. Expenditures for the first two years of the project were for data entry (2000-2001), and the development of the balsam fir and spruce - balsam fir SDMD's (2001-2002). Although not explicitly shown in the tables listed below, the data sets provided by the partners and collaborators represent millions of dollars worth of wages and resources. Some of the past research projects for these data sets often cover the career span of several research scientists. In real dollars the cost to develop the SDMD's was a small portion of the total cost, because without the available data sets from many agencies their construction would not have been possible. Most of the current project expenditures were for the development of a spruce (red /black) SDMD's and refinement of features in the supporting software (Table 3). Potential users and project committee members wanted more software options and features to be included into the supporting software, rather than a costly CD disk containing the software. Also most of the users felt that since the software would be available from a website, they would rather spend the existing funds on enhancing the software.

Table 1. Project funding for the 2000-2002.

Agency	Cash	In-Kind Funding
Fundy Model Forest	$ 16,500	
Natural Resources Canada, Canadian Forest Service	$ 700	$ 40,000*; data sets
USDA Forest Service		data sets
J.D. Irving Ltd		data sets
Southern New Brunswick Wood Co-operative Ltd.		data sets
Ontario Ministry of Natural Resources		software, advice
Quebec Ministry of Natural Resources		data sets
Laval Universite		data sets
Universite de Moncton		B.Sc.F. Thesis Work
Total	$ 17,200	

* computer, laboratory faculties, etc.

Table 2 . Project funding for the last year, 2002-2003.

Agency	Cash	In-Kind Funding
Fundy Model Forest	$8,500	
Natural Resources Canada, Canadian Forest Service		20,000*, data sets
USDA Forest Service		data sets
J.D. Irving Ltd	$3,000	data sets
Southern New Brunswick Wood Co-operative Ltd.		data sets
Ontario Ministry of Natural Resources		10,000**
Quebec Ministry of Natural Resources		data sets
Laval Universite		data sets
Universite de Moncton		B.Sc.F. Thesis Work
Maritime Forest Ranger School		Workshop Location
Total	$11,500	

* computer, laboratory faculties, etc. ** supporting software, technical assistance, and advice.

Table 3. Listing of expenditures for 2002-2003

Item	Cost
Revisions to existing software (OMNR) as suggested by the users: 1) Reorganized the project (source code); 2) Improved the Plot Data dialog. Now you can have empty cells in the grid, 3) Added new toolbar button to Remove rows; 4) Added menu to complement toolbar icons; 5) Added a menu and toolbar icon to close all open windows; 6) Added option "Auto Thin" to Graph and Popup menus that allow thinning a specified number of times to a maximum limit of 5 thinning operations; 7) Added "Project to DBHq" and "Project Height" options to the Graph and Popup menu. This feature allows quick toggle between "Thin at Mort line Init", "Project to DBHq" and "Project to Ht". i.e. Thinning options are not easily accessible;. 8) Plot Data dialog now have tool tips on the toolbar; 9) Existing stand dialog will reset to 0 the Stand Height/Diameter when the stand attributes are changed; and 10) Added MinAge in the GetAge_HtSi() calculation to all species minus the black spruce (OMNR).	$ 1,500
Development of a SDMD for spruce (red /black).	$ 4,600
Incorporation of the spruce (red /black) SDMD into existing software.	$ 2,000
Comparison of balsam fir growth and yield from the Green River data to the data that was used to develop the NB balsam fir SDMD.	$ 2,300
Development of a user's guide as a B.Sc.F. Thesis*	$800
Miscellaneous Expenses	$300
Total	$11,500

* on-going, completion date: 15 December 2003.

DELIVERABLES

PRESENT

By the end of Phase II of the Fundy Model Forest, this cooperative project has produced the three following SDMD's for the Acadian Forest Region: 1) balsam-fir (Figures 2 and 3), 2) spruce - balsam fir (Figure 4 and 5), and 3) spruce (red / black) (Figure 6). A beta version containing the balsam fir SDMD was released to the participants at the workshop conducted by the Fundy Model Forest last May. Based on recommendations from the survey that was sent to the potential users of the management tool, additional options and features were added to the existing SDMD software to produce the CD on the back cover of this report. Therefore, the project has successfully completed past objectives and the following four current objectives:

1) Release of a beta version;
2) Dissemination of the SDMD and supporting software through instructional workshops;
3) Testing of the beta version; and
4) Refinement of the beta version into the first general release of the CD for SDMD's that were produced for the Fundy Model Forest.

FUTURE

Internal reports for the development of the balsam fir - spruce and spruce (red / black) SDMD's are under the peer review process at the Canadian Forest Service, Atlantic Forestry Centre. A peer reviewed journal article is being written that describes the development of the three SDMD's for the Acadian Forest Region. Also planned is a journal article on the comparison of the balsam fir growth and yield from the Green River spacing data to the data that was used to develop the New Brunswick balsam fir SDMD. Material has been sent to the Fundy Model Forest for the production of a poster for a side event at IUFRO World Forestry Congress in 2003.

CONCLUSIONS

1) At the end of Phase II, the SDMD project has met the original objectives of producing another tool (three SDMD's) for stand density management in the Acadian Forest Region.

2) The success of the project was realized through the cooperative efforts of many individuals from various forestry organizations Some of partners / collaborators of the project provided data sets to be used for the development of the SDMD's.

3) The workshop held in May 2002 has assisted in the development, assessment, demonstration, and technology transfer of a stand density management tool for sustainable forest and ecosystem management.

4) The workshop in May 2002 has provided information, general education, training, and professional development for researchers, forest managers and woodlot owners from across eastern North America.

5) SDMD's exist at different levels of complexity depending on existing data and intended use by the developers (Farnden 2002). The SDMD's produced by the Fundy Model Forest are very complex models, but lack size-density (mortality) trajectories. This does not imply that the existing Fundy Model Forest SDMD's are not useful management tools as they exist. Data is available for the development of the balsam fir SDMD, and possibly with the other Fundy Model Forest SDMD's. Hence, mortality curves should be developed for the eastern spruce - balsam fir SDMD's of the Acadian Forest Region.

6) Increase emphasis should be placed on technology transfer of the existing SDMD's to potential users in and outside of the Fundy Model Forest.

7) Where possible, linkages should be encouraged between the three Model Forests (Fundy Model Forest, Nova Forest Alliance Model Forest, and Western Newfoundland Model Forest) with future development and refinement of SDMD's.

8) The existing SDMD's for the eastern spruce - balsam fir forest of the Acadian Forest Region should undergo extensive testing by the partners of the Fundy Model Forest.

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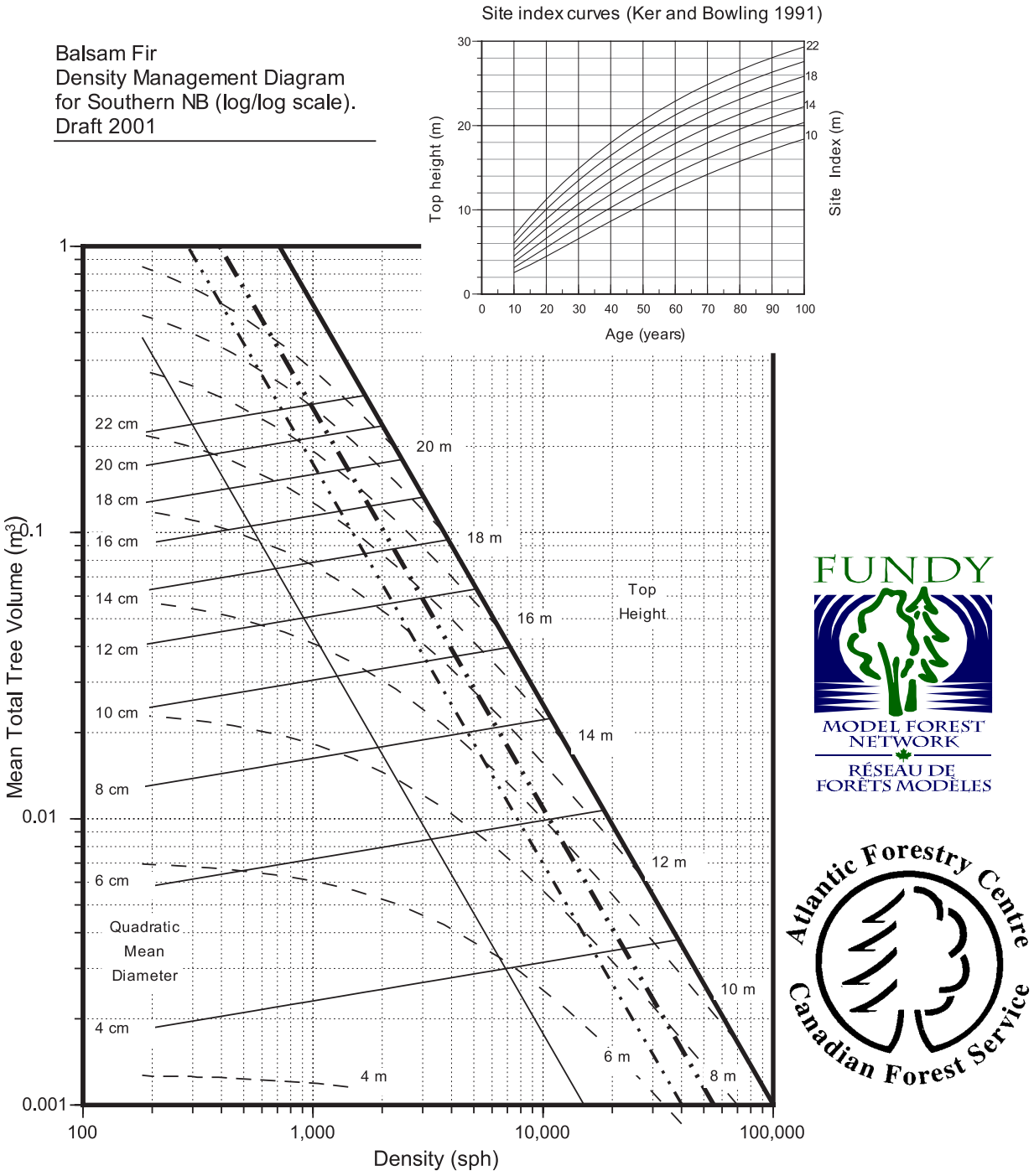

Figure 2. Balsam fir stand density management diagram for the Acadian Forest Region.

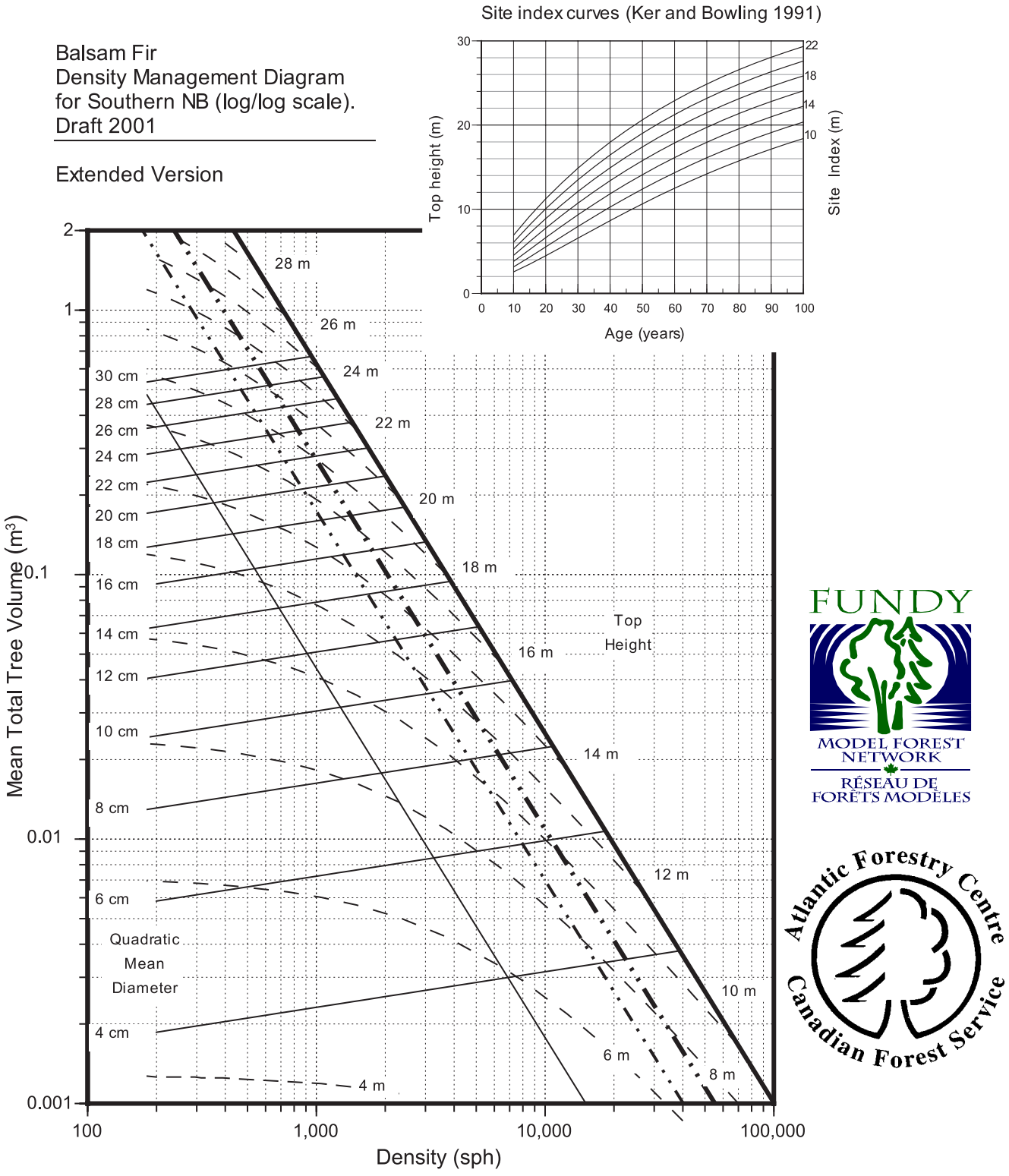

Figure 3. Extended version of the balsam fir stand density management diagram for the Acadian Forest Region.

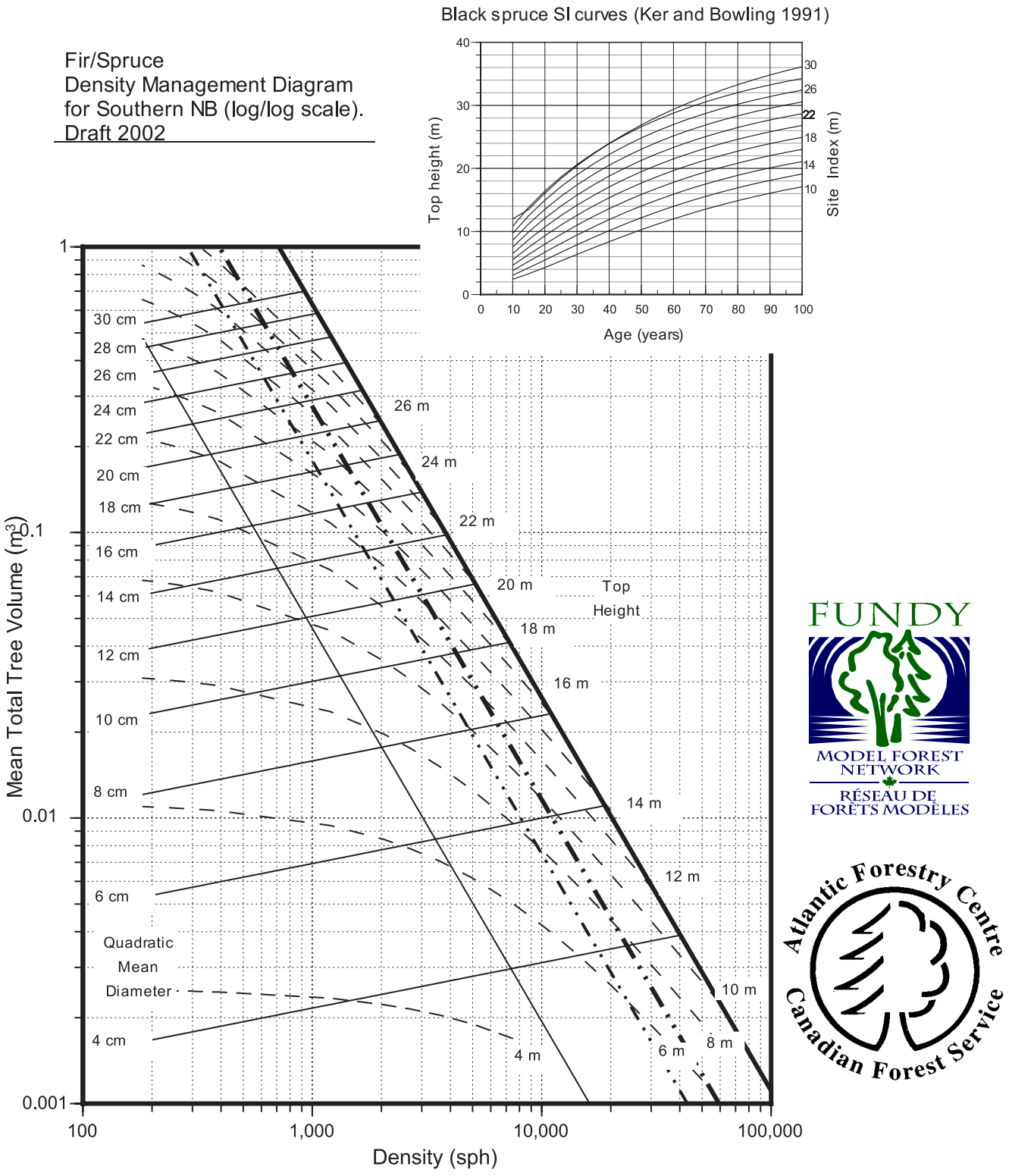

Figure 4. Spruce – balsam fir stand density management diagram for spruce /fir mixtures (50/50 mixtures by basal area) of the Acadian Forest Region, black spruce site index curves are provided.

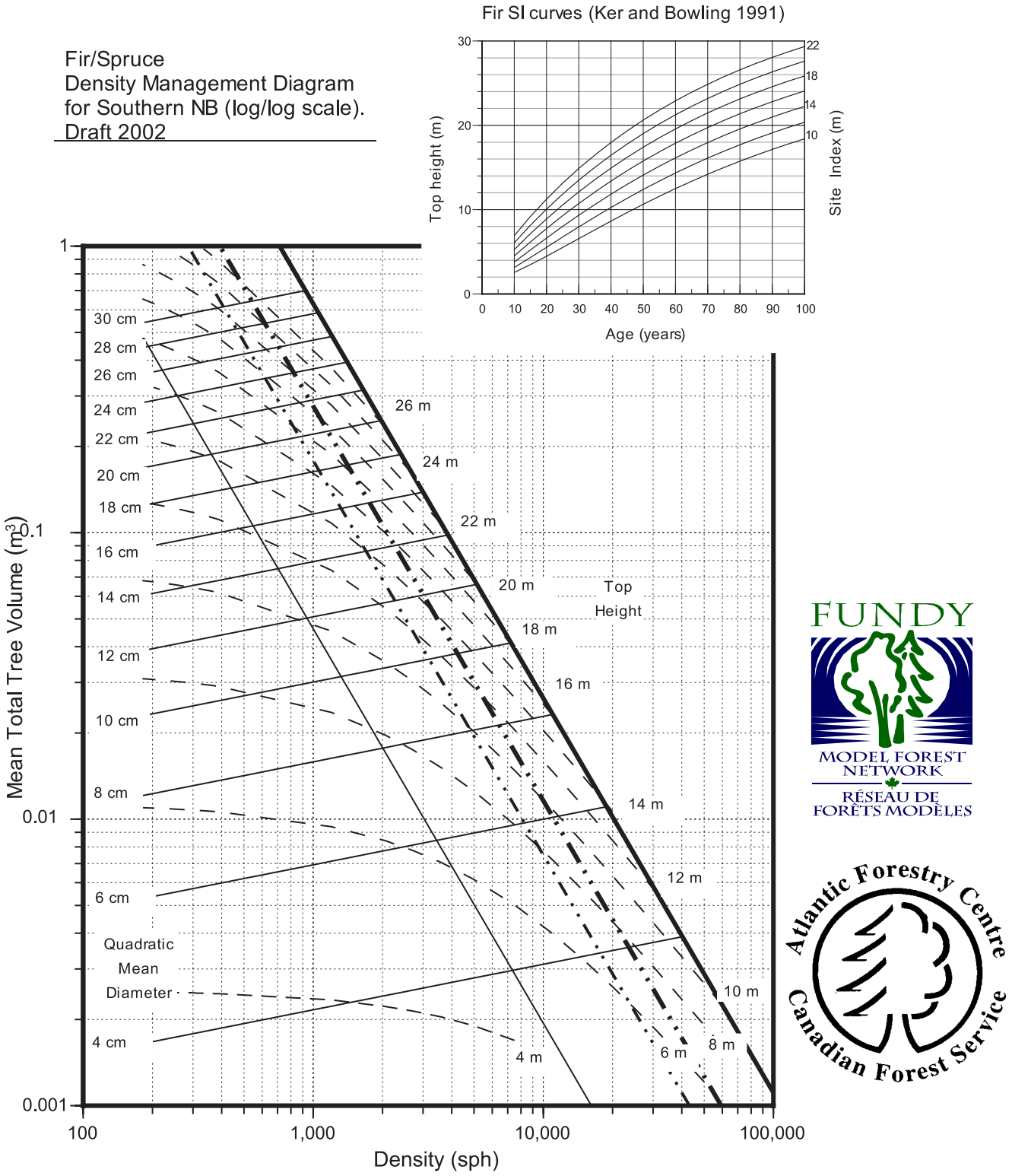

Figure 5. Spruce – balsam fir stand density management diagram for spruce /fir mixtures (50/50 mixtures by basal area) of the Acadian Forest Region, balsam fir site index curves are provided

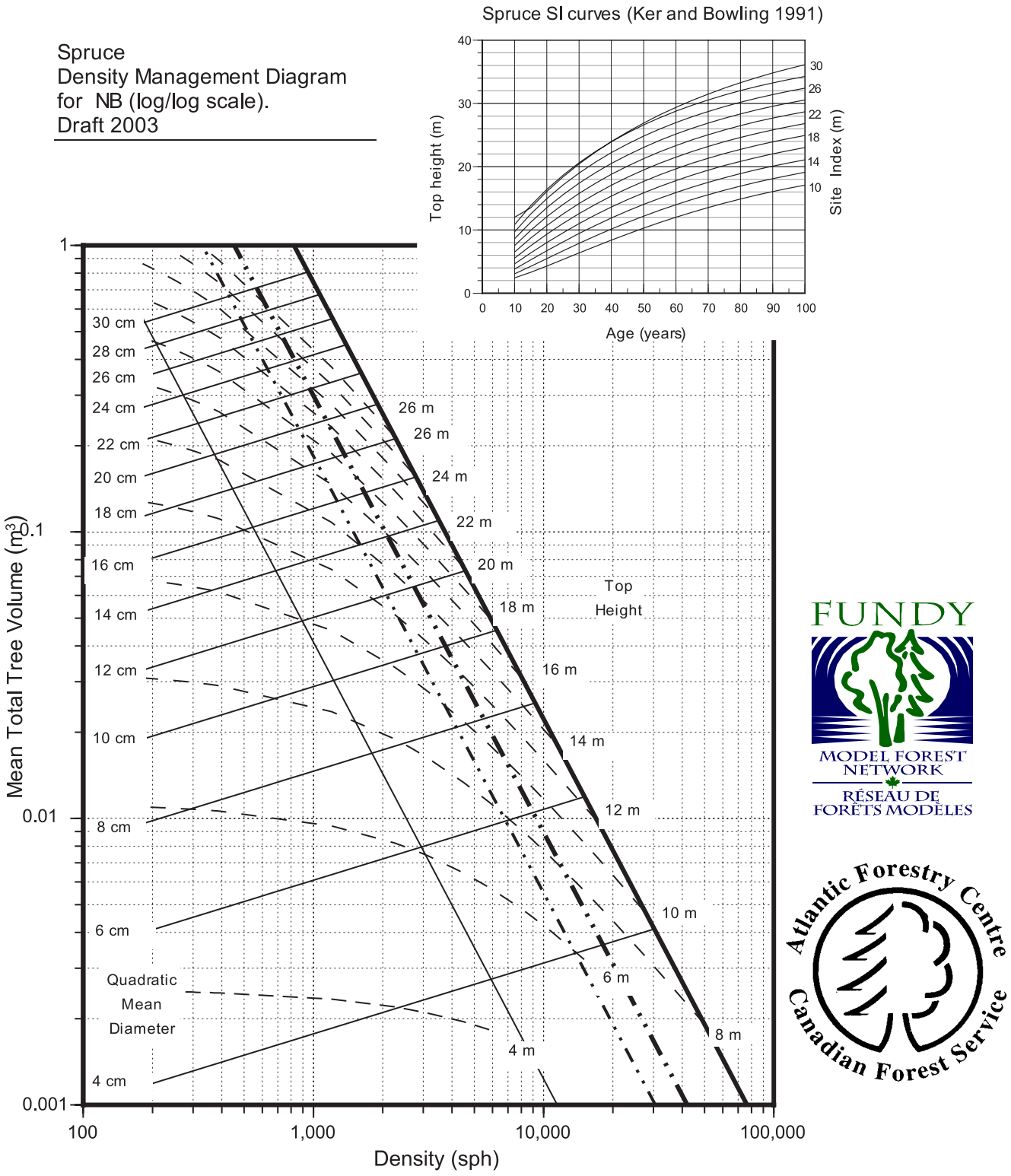

Figure 6. Spruce (red / black) stand density management diagram for the Acadian Forest Region.