PROVISIONAL STAND DENSITY MANAGEMENT DECISION-SUPPORT MODELS FOR BOREAL CONIFERS

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ABSTRACT

Based on the modelling approach underlying the development of dynamic stand density management diagrams, the objective of this study was to develop stand density management decision-support models for the following stand-types: unmanaged (natural) and managed (plantations) upland black spruce (*Picea mariana* (Mill.)) stands; unmanaged and managed jack pine stands; mixed unmanaged natural black spruce and jack pine (*Pinus banksiana* Lamb.) stands; and lowland black spruce stands. The database used to construct the models consisted of 1874 stand-level measurements derived from 749 permanent and temporary sample plots situated principally within the boreal region of the Province of Ontario. The models were developed employing the following analytical steps: (1) determination of the stand-type-specific asymptotic mean volume-density relationship via the use of bisector regression analysis in combination with an objective data selection protocol; (2) given (1), determination of stand-type-specific relative density index functions and subsequent delineation of the optimal density management window as defined by the size-density condition at which density-effects on yield are initiated (lower limit) and by the size-density condition at which the mean live crown ratio attains an asymptotic value, past which responses to thinning would be minimal; (3) determination of stand-type-specific relationships for estimating quadratic mean diameter, dominant height and merchantability ratio via multiple regression analysis; and (4) determination of stand-type-specific size-density trajectories. The resultant models enable managers to simultaneously predict and subsequently contrast complex density management regimes in terms of rotational yields. Current research includes software development, accuracy testing and model extension.

Keywords: natural and managed, upland and lowland black spruce and jack pine stand-types.
INTRODUCTION

The stand density management diagram (SDMD) is a graphical decision-support aid that is used by forest managers to determine density management regimes that are required for the realization of specific stand-level management objectives (e.g., maximizing rotational yields, product value or the period of optimal site occupancy (Newton 2003a)). Structurally, SDMDs consist of a number of functional and empirical quantitative relationships, which collectively represented the cumulative effect of various underlying competition processes on tree and stand yield attributes. The temporal dependency of these processes is governed by the intensity of competition and site quality as expressed by relative density index and site index, respectively. Although classified as stand-level distance-independent average tree models, SDMDs can be further subdivided into either static or dynamic model types. Static SDMDs lack a mortality sub-model within their structure and hence cannot describe stand developmental pathways that include density-dependent mortality. Conversely, dynamic SDMDs are those that explicitly include a mortality sub-model within their structure and hence are more applicable in density management decision-making.

Given the rapid increase in the complexity of density treatments within boreal stand-types, the utility of existing static SDMDs and their algorithmic analogues, has become limited. Consequently, the objective of this study was to develop dynamic SDMDs for the following stand-types: unmanaged and managed upland black spruce (Picea mariana (Mill.)) stands (denoted PlmUL(N) and PlmUL(M), respectively) unmanaged and managed jack pine (Pinus banksiana Lamb.) stands (denoted PNb(N) and PNb(M), respectively); mixed unmanaged natural black spruce and jack pine stands (denoted Plm+PNb(N)); and lowland black spruce stands (denoted PlmLL(N)).

METHOD

The database used to construct the models consisted of 1874 stand-level measurements derived from 749 permanent and temporary sample plots situated principally within the boreal region of the Province of Ontario: 122 PlmUL(N) measurements, 392 PlmUL(M) measurements; 262 PNb(N) measurements, 221 PNb(M) measurements, 382 Plm+PNb(N) measurements and 495 PlmLL(N) measurements. The following analytical steps were used to develop the SDMDs: (1) determination of the stand-type-specific asymptotic mean volume-density relationship via the use of bisector regression analysis in combination with an objective data selection protocol; (2) given (1), determination of stand-type-specific relative density index functions and subsequent delineation of the optimal density management window as defined by the size-density condition at which density-effects on yield are initiated (lower limit) and by the size-density condition at which the mean live crown ratio attains an asymptotic value, past which responses to thinning would be minimal (upper limit); (3) determination of stand-type-specific relationships for estimating quadratic mean diameter, dominant height and merchantability ratio via multiple regression analysis; and (4) determination of stand-type-specific size-density trajectories based on Hagihara’s (1998) model.
RESULTS AND DISCUSSION

The resultant SDMD’s are graphically illustrated in Figures 1-6 by stand type. The principal relationships of the SDMDs include isolines for mean dominant height, quadratic mean diameter, merchantability ratio, and relative density index, the asymptotic mean-volume density condition (self-thinning rule), expected size-density trajectories for given establishment densities, and an optimal density management window.

Figure 1. Graphical illustration of the SDMD for upland black spruce stands. Note the following principal components of the SDMD: (1) isolines for mean dominant height (Hd; 6-20 m by 2m intervals), quadratic mean diameter (Dq; 4-20 cm by 2cm intervals), merchantability ratio (Mr; 0.4-0.8 by 0.2 intervals), relative density index (Pr; 0.1-1.0 by 0.1 intervals); (2) self-thinning rule at a Pr = 1.0; (3) stand developmental guide curves for expected size-density trajectories for establishment densities of 1000-10000 by 1000 stems/ha intervals (Tr); and (4) lower and upper Pr values delineating the optimal density management window (Dm).
Figure 2. Graphical illustration of the SDMD for managed upland black spruce stands. Note the following principal components of the SDMD: (1) isolines for mean dominant height (Hd; 4-20 m by 2m intervals), quadratic mean diameter (Dq; 4-20 cm by 2cm intervals), merchantability ratio (Mr; 0.4-0.8 by 0.2 intervals), relative density index (Pr; 0.1-1.0 by 0.1 intervals); (2) self-thinning rule at a Pr = 1.0; (3) stand developmental guide curves for expected size-density trajectories for establishment densities of 1000-10000 by 1000 stems/ha intervals (Tr); and (4) lower and upper Pr values delineating the optimal density management window (Dm).
Figure 3. Graphical illustration of the SDMD for jack pine stands. Note the following principal components of the SDMD: (1) isolines for mean dominant height (Hd; 4-20 m by 2m intervals), quadratic mean diameter (Dq; 4-20 cm by 2cm intervals), merchantability ratio (Mr; 0.4-0.8 by 0.2 intervals), relative density index (Pr; 0.1-1.0 by 0.1 intervals); (2) self-thinning rule at a Pr = 1.0; (3) stand developmental guide curves for expected size-density trajectories for establishment densities of 1000-10000 by 1000 stems/ha intervals (Tr); and (4) lower and upper Pr values delineating the optimal density management window (Dm).
Figure 4. Graphical illustration of the SDMD for managed jack pine stands. Note the following principal components of the SDMD: (1) isolines for mean dominant height (Hd; 4-20 m by 2 m intervals), quadratic mean diameter (Dq; 4-20 cm by 2 cm intervals), merchantability ratio (Mr; 0.4-0.8 by 0.2 intervals), relative density index (Pr; 0.1-1.0 by 0.1 intervals); (2) self-thinning rule at a Pr = 1.0; (3) stand developmental guide curves for expected 100 year size-density trajectories for establishment densities of 1000-10000 by 1000 stems/ha intervals (Tr); and (4) lower and upper Pr values delineating the optimal density management window (Dm).
**Figure 5.** Graphical illustration of the SDMD for mixed black spruce and jack pine stands. Note the following principal components of the SDMD: (1) isolines for mean dominant height (Hd; 6-20 m by 2m intervals), quadratic mean diameter (Dq; 4-20 cm by 2cm intervals), merchantability ratio (Mr; 0.4-0.8 by 0.2 intervals), relative density index (Pr; 0.1-1.0 by 0.1 intervals); (2) self-thinning rule at a Pr = 1.0; (3) stand developmental guide curves for expected size-density trajectories for establishment densities of 1000-10000 by 1000 stems/ha intervals (Tr); and (4) lower and upper Pr values delineating the optimal density management window (Dm).
Figure 6. Graphical illustration of the SDMD for lowland black spruce stands. Note the following principal components of the SDMD: (1) isolines for mean dominant height (Hd; 6-20 m by 2m intervals), quadratic mean diameter (Dq; 4-20 cm by 2cm intervals), merchantability ratio (Mr; 0.4-0.8 by 0.2 intervals), relative density index (Pr; 0.1-1.0 by 0.1 intervals); (2) self-thinning rule at a Pr = 1.0; (3) stand developmental guide curves for expected size-density trajectories for establishment densities of 1000-10000 by 1000 stems/ha intervals (Tr); and (4) lower and upper Pr values delineating the optimal density management window (Dm).
These new dynamic SDMDs are an enhancement over existing static SDMDs given their ability to explicitly describe the size-density trajectory during self-thinning events. However, further model evaluation in terms of accuracy testing is required before the SDMDs can be applied operationally (e.g., Newton 2003b). Furthermore, software versions need to be developed in order to facilitate their utility in density management decision-making.

Currently, in addition to accuracy testing and software development, research efforts are focused on extending these models to stand-level distance-independent diameter distribution models using the parameter prediction approach proposed by Hyink and Moser (1983). The resultant extended models will enable the prediction of diameter class yields and hence the ability to derive optimal density management regimes based on product value maximization (e.g., Newton et al. 2004).

REFERENCES


