A POSSIBILITY OF THE STRUCTURE MODELING IN ARTIFICIAL EVEN-AGED SPRUCE STAND AFFECTED BY BIOTIC DISTURBANCES FACTORS

RADU VLAD
Forest Research and Management Institute, Câmpulung Moldovenesc Station, Romania

ABSTRACT

The paper presents the results of the research carried out in artificial even-aged spruce stands, regarding the modelling of the biometric parameters (distribution of the deer damaged trees on the diameter classes) and quality parameters (dynamic of the volume with stem decay). The main studied topics were: regression equations witch represent relations between the Charlier distribution parameters (standard deviation, asymmetry, kurtosis) and the frequency of the deer damages; structural models of the deer damaged trees distribution on the diameter classes correlated with the frequency of the deer damages; structural models of the volume dynamic with stem decay on the diameter classes correlated with the frequency of the deer damages, all based on the Charlier distribution.

Using an original method, it was possible to establish a model predicting the deer damaged trees distribution on the diameter classes, and a model predicting the dynamics of the volume with stem decay on the diameter classes, all based on the relationship between frequencies of the deer damages and stand development in artificial even-aged spruce forests.

This research brought up some unknown aspects that can be considered as new contributions concerning scientific basis for the sustainable forest management in mountains ecosystems affected by biotic disturbances factors.
Keywords: spruce, structure modelling, deer damage, stem decay

INTRODUCTION

Models of forest growth, from the initial sketched diagrams to sophisticated computer models, have been and still are important forest management tools. The first modeless facing the challenge to simulate forest growth took the traditional and empirical yield table as a start point (Wiedemann, 1949; Almi, Barrett, 1977; Deusen, Biging, 1985). Empirical growth and yield models developed recently are mostly tree-level (Biging, Dobbertin, 1995). The major drawback of the empirical approach, where tree or stand growth is estimated using descriptive relationships, is the restricted applicability of the models due to the limited validity of the empirical relationships, even they have a great resolution give by the computer. These models do contain mechanistic relationships, but also draw heavily on tree allometry; they combine functional relationships with a tree-based simulation approach.

Apart from the difference between empirical and mechanistic model, a distinction can be made to spatial resolution, between stand-level and tree level approaches. Most stand-level models are empirical models, such as the yield tables. Stand-level models are by their very nature unable to represent different pattern, or to take account of spatially non-systematic thinning measures. Neither can they take crown dynamic into account. In contrast, some of the more recently developed growth and yield models are tree-level, modelling individual trees either empirical (Leersnijder, 1992; Pretzsch, 1992) or more mechanistically (Szwagrzyk, 1997; Bartelnik, 1998).

One of the first modelling attempting aiming specifically at simulating mixed forest growth was development of the 'gap-models' (Botkin, 1972). 'Gap-models' can be classified as a special category of the tree-level modelling, as they define and keep track of individual trees competing and growing in a restricted area, the gap (Botkin, 1972; Shugart, 1984; Kienast, Kuhn, 1989; Leemans, 1992; Fischlin, 1995; Jorristma, 1999). Gap-models and tree-level models are more flexible than stand-level models, but generally heavily on descriptive relationship. Models that include biological processes and are suitable to support taking decisions about forest management would constitute a great advantage, but unfortunately are still scarce (Mohren, 1991). On the other hand, though mechanistic conditions approaches do relate growth to growing conditions, these are in general too theoretical or require too many data to be much value for forest managers.

A possibility of the structure modelling in artificial even-aged spruce stand affected by biotic disturbances factors, must take into consideration capitals problems of the forest management from different forest zone. These are ecologic problems and considered in reconstruction of the ecosystems affected by management, especially a wrong management of the old-growths stand with natural and stabile structure (Ichim, 1975, 1990; Giurgiu, 1978).

Usually, in spruce stands only the wind with a great intensity was considered dangerous factor producing calamities, but it is less shown that red decay, caused by deer damages and being located on the trees stem determines calamities, which caused irreversible qualitative losses of the wood volume. Also, stem decay in affected spruce stands it is one of the encouraging factors that determinate tears and throwing down by snow and wind (Ichim, 1975, 1990; Giurgiu, 1979).

The main research objectives were:

- Dynamic and modelling biometric parameters in the spruce stands affected by biotic disturbances factors (distribution of the tree damaged by deer on the diameter classes);

- Dynamic and modelling qualitative parameters in the spruce stands affected by biotic disturbances factors (distribution of the wood volume with stem decay, caused by deer damages, on the diameter classes);

Materials and methods

The researches were localized in representative zones with a great ecological and economical impact caused by biotic disturbances factors (deer) on artificial even-aged spruce stands. Ground works were spread out in forest districts Iacobeni, Moldovita, Pojorâta, Vama (forest direction Suceava) and in experiment forest district Tomnatic (I.C.A.S.). There have been studied in spruce stands with high productivity affected by deer damages, about 21-80 years old, from next development stages: pole stage, young timber stage and mature timber stage.

Researches development was based on the methods for ground works like statistical inventory, based on the knowledge methodology (Ichim, R., 1975, 1990; Alexe, A., Milescu, I., 1983) in 120 stands (1225 experimental loose plots). Primary dates from the ground was: diameter to 2,0 m for the trees damaged by deer; diameter to 1,30 m for healthy trees from the stand; height of 20 - 25 trees, age of the deer damage for 20 - 25 trees, being care for take in account all diameter classes.

Ground data processing was made bedding spruce stands damage by deer on development stage, taking into account the value of the DBH (pole stage - DBH = 10-20 cm, young timber stage - DBH = 20-35 cm, mature timber stage - DBH = 35-50 cm). Because of the large data sets from statistically investigations, it was necessary to use informatics technique. It was made specific data base for the relationship analysis and for a good management of the statistic dates. We used statistical methods and mathematics modelling, each in correlation with the main studied topic objectives of the researches.

To set out a better theoretical repartition near to experimental distribution, for the number of the trees damaged by deer and for the stem decay, in spruce stands damaged by this biotic disturbance factor, it was made a characterization of the spruce even-aged structure using frequency function of the Charlier distribution (type A) (Giurgiu, 1972; Leahu, 1994, (Vlad, 2002 a). That theoretical function takes into consideration standard deviation (s), asymmetry (a) and kurtosis (e) of the experimental distributions.

For specific structure of the trees number distribution, it is necessary to understand the dimensional variability of them. In artificial even-aged stands a little number of favoured trees develops to big diameters through obstruction of numerous trees with small diameters (Chertov et al., 1998; Hanewinkel, Pretzsch, 1999; Zeide, Zhang, 1999). This fact induces the idea that trees distribution to the diameter classes, graphically characterized through a certain asymmetry and kurtosis, is more complex than normal distribution curve (Lähde et al., 1993; Kolström, 1993; Pretzsch, 1997; Bartelnik, 1999; Porté, Bartelnik, 2001).

It was proved that the number of the parameters into the repartition function of the trees on the diameter classes is higher than the parameters from the normal distribution. Consequently the structure of the even-aged should be described by complex and flexible frequency curves (Giurgiu, 1979; Leahu, 1994).

Dynamic and modelling qualitative parameters in the spruce stands affected by biotic disturbances factors was based on the study of the volume dynamic on the primary and dimensional assortments in spruce stands damaged by deer. The procedure to determinate the volume engaged of the wood with stem decay (%) was finalized into an automatic program that necessitates a lot of stages.

Concrete, it was established the distribution of the wood volume with stem decay produced by deer damages on diameter classes (%), correlated with damage frequency and age of the damages, in spruce stands about 21-80 years old and with different values of the damaged trees percent.

It was possible to establish some correlatives coupling between Charlier distribution parameters (standard deviation - s, asymmetry - a, kurtosis - e) and damage frequency (%Vn), considering the development stage.

The main studied topics were:

- Correlations between Charlier distribution parameters (standard deviation - s, asymmetry - a, kurtosis - e) and damages frequency (%Vn), for spruce stands damaged by deer about 21-80 years old, depending on development stage;
- Established the regression equations witch represented connection between Charlier distribution parameters (standard deviation - s, asymmetry - a, kurtosis - e) and damage frequency (%Vn), for spruce stands damaged by deer about 21-80 years old, depending on characteristic development stage;
- Determinate the mathematic expression models witch represent distribution of the tree damaged by deer on the diameter classes and distribution of the wood volume with stem decay on the diameter classes, correlated with damages frequency (%Vn) (values of the percentage for 10 % to 100 %), in spruce stands damaged by deer into development stage of pole stage, young timber stage and mature timber stage;

Results

Structural models which represent the distribution of the trees damaged by deer on the diameter classes in affected spruce stands

Taken notice about characteristics and specificity of the correlative regressions analyzed, table 1 present regression equations who represented connection between Charlier distribution parameters (standard deviation - s, asymmetry - a, kurtosis - e) and damages frequency (%Vn), in affected spruce stands.

Table 1. Regression equations that represented connection between Charlier distribution parameters (standard deviation - s, asymmetry - a, kurtosis - e) and damages frequency (%Vn)

Development stage	Charlier distribution parameters	Regression equations		Correlation coefficient	Cases number
Pole stage	Standard deviation	s = 5,528 □(%V_n)^{0,1307}	(1)	r=0,642***	40
	Asymmetry	á = - 0,0058 □(%V_n) + 1,0579	(2)	r=0,698***	40
	Kurtosis	Í = - 0,0135 □(%V_n) – 0,278	(3)	r=0,735***	40
Young timber stage	Standard deviation	s = 5,1128 □(%V_n)^{0,1803}	(4)	r=0,746***	40
	Asymmetry	á = - 0,0049 □(%V_n) + 0,7619	(5)	r=0,625***	40
	Kurtosis	Í = - 0,014 □(%V_n)– 0,2377	(6)	r=0,697***	40
Mature timber stage	Standard deviation	s = 7,6 □(%V_n)^{0,1464}	(7)	r=0,525***	40
	Asymmetry	á = - 0,0073 □(%V_n) + 0,82	(8)	r=0,578***	40
	Kurtosis	Í = - 0,008 □(%V_n) – 0,4035	(9)	r=0,706***	40

Note: *** - high significance

Analyzing the significance of the correlations presented in table 1, it was established a strong (very strong in some cases) correlation, with high significance between damage frequency (%Vn) and some parameters from Charlier distribution (standard deviation - s, asymmetry - a, kurtosis - e), different from development stage of the artificial spruce even-age stands.

Using the parameters from Charlier distribution established depending on value of the damage percentage, adjusting absolute frequency $(\hat{n})$ in percents $\hat{n} = \frac{\hat{n}}{N} \cdot 100$ known the regression equations (1) - (9) and considered classes diameter interval about 4 cm, it was obtained the following mathematic models which give information about structure of the spruce stands damaged by deer. They show the distribution of the tree damaged by deer on the diameter classes in affected spruce stands, for values of the damage percentage about 10 % to 100 %.

Expressions, depending on specific development stage, are listed below:

- Pole stage; DBH = 10-20 cm

$$\hat{n}\% = \frac{400}{5{,}528 \cdot (\%V_{n(10,...,100)})^{0{,}1307}} \cdot \left[f_{(u)} - \frac{-0{,}0058 \cdot \%V_{n(10,....,100)} + 1{,}0579}{6} \cdot f^{III}_{(u)} + \frac{-0{,}0135 \cdot \%V_{n(10,....,100)} - 0{,}278}{24} \cdot f^{IV}_{(u)} \right] \quad (10)$$

$$\hat{n}\% = \frac{400}{5{,}1128 \cdot (\%V_{n(10,...,100)})^{0{,}1803}} \cdot \left[f_{(u)} - \frac{-0{,}0049 \cdot \%V_{n(10,....,100)} + 0{,}7619}{6} \cdot f^{III}_{(u)} + \frac{-0{,}014 \cdot \%V_{n(10,....,100)} - 0{,}2377}{24} \cdot f^{IV}_{(u)} \right]$$

- Young timber stage; DBH = 20-35 cm (11)

$$\hat{n}\% = \frac{400}{7{,}6 \cdot (\%V_{n(10,\ldots,80)})^{0{,}1464}} \cdot \left[f_{(u)} - \frac{-0{,}0073 \cdot \%V_{n(10,\ldots,80)} + 0{,}82}{6} \cdot f_{(u)}^{III} + \frac{-0{,}008 \cdot \%V_{n(10,\ldots,80)} - 0{,}4035}{24} \cdot f_{(u)}^{IV} \right]$$

- Mature timber stage; DBH = 35-50 cm

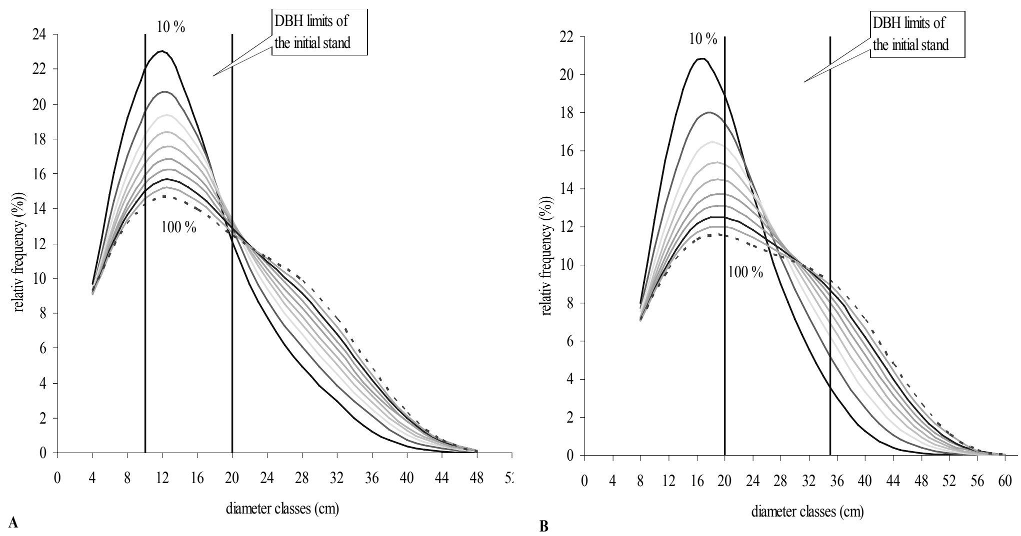
(12)

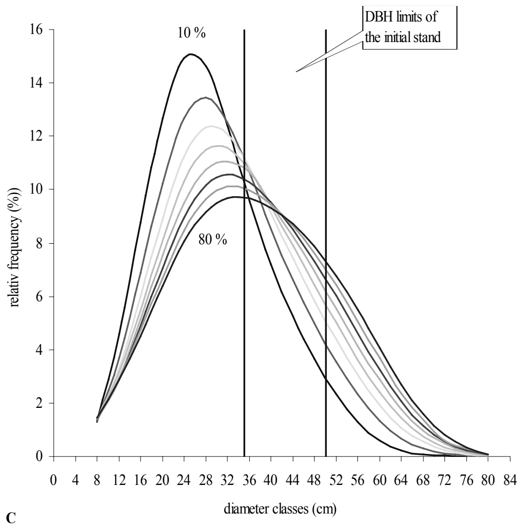
Figure 1 presents structural models, in spruce even-aged spruce stands, witch show the distribution of the trees damaged by deer on the diameter classes, correlated with damage frequency (%) and development stage.

Structural models which represent the distribution of the volume affected by stem decay on the diameter classes in damaged spruce stands

Table 2 present regression equations which represent connection between Charlier distribution parameters (standard deviation - s, asymmetry - a, kurtosis - e) and damage frequency (%Vn), for quantification of the volume affected by stem decay on diameter classes, in affected spruce stands.

Analyzing the significance of the correlations presented in table 2, it was established a strong (very strong in some cases) correlation, with high significance between damage frequency (%Vn) and the analyzed parameters from Charlier distribution (standard deviation - s, asymmetry - a, kurtosis - e), different from development stage of the artificial spruce even-age stands.





C

Figure1. Structural model about distribution of the trees damaged by deer on the diameter classes, correlated with damage frequency (%)
A - Pole stage;
B - Young timber stage;
C - Mature timber stage.

Table 2. Regression equations that represented connection between Charlier distribution parameters (standard deviation - s, asymmetry - a, kurtosis - e) and damages frequency (%Vn)

Development stage	Charlier distribution parameters	Regression equations		Correlation coefficient	Cases number
Pole stage	Standard deviation	$s = 5,359\ \square(\%V_n)^{0,1469}$	(13)	r=0,760***	40
	Asymmetry	á = - 0,4581 □Ln(%V_n) + 2,3731	(14)	r=0,577***	40
	Kurtosis	Í = - 1,3105 □Ln(%V_n) + 4,6873	(15)	r=0,932***	40
Young timber stage	Standard deviation	$s = 6,9167\ \square(\%V_n)^{0,1151}$	(16)	r=0,555***	40
	Asymmetry	á = - 0,2789 □Ln(%V_n) + 1,6245	(17)	r=0,559***	40
	Kurtosis	Í = - 0,4725 □Ln(%V_n) + 1,3841	(18)	r=0,507***	40
Mature timber stage	Standard deviation	$s = 7,3925\ \square(\%V_n)^{0,1585}$	(19)	r=0,507***	40
	Asymmetry	á = - 0,365 □Ln(%V_n) + 1,9406	(20)	r=0,674***	40
	Kurtosis	Í = - 0,4552 □Ln(%V_n) + 0,924	(21)	r=0,504***	40

Note: *** - high significance

Taking into account the formulas (13) - (21) it was obtained the mathematic models expressions of the volume distribution affected by stem decay on the diameter classes, in damaged spruce stands, which are listed below:

- Pole stage; DBH = 10-20 cm

$$\hat{n}\% = \frac{400}{5,359 \cdot (\%V_{n(10,...,100)})^{0,1469}} \cdot \left[f_{(u)} - \frac{-0,4581 \cdot Ln\%V_{n(10,...,100)} + 2,3731}{6} \cdot f_{(u)}^{III} + \frac{-1,3105 \cdot Ln\%V_{n(10,...,100)} + 4,6873}{24} \cdot f_{(u)}^{IV} \right]$$

(22)

$$\hat{n\%} = \frac{400}{6{,}9167 \cdot (\%V_{n(10,\ldots,100)})^{0{,}1151}} \cdot \left[f_{(u)} - \frac{-0{,}2789 \cdot Ln\%V_{n(10,\ldots,100)} + 1{,}6245}{6} \cdot f_{(u)}^{III} + \frac{-0{,}4725 \cdot Ln\%V_{n(10,\ldots,100)} + 1{,}3841}{24} \cdot f_{(u)}^{IV} \right]$$

- Young timber stage; DBH = 20-35 cm (23)

$$\hat{n\%} = \frac{400}{7{,}3925 \cdot (\%V_{n(10,\ldots,80)})^{0{,}1585}} \cdot \left[f_{(u)} - \frac{-0{,}365 \cdot Ln\%V_{n(10,\ldots,80)} + 1{,}9406}{6} \cdot f_{(u)}^{III} + \frac{-0{,}4552 \cdot Ln\%V_{n(10,\ldots,80)} - 0{,}924}{24} \cdot f_{(u)}^{IV} \right]$$

- Mature timber stage; DBH = 35-50 cm

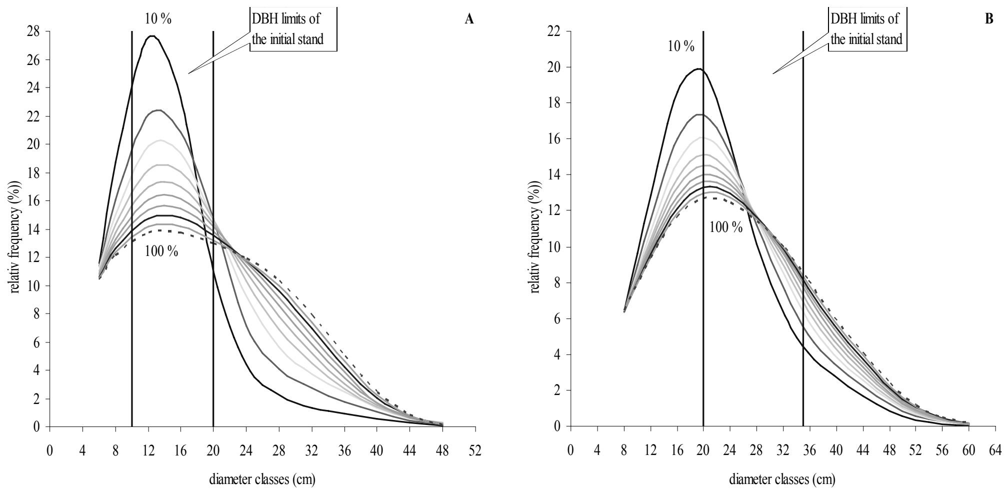
(24)

Structural models, in spruce even-aged spruce stands, witch shown distribution of the affected volume by stem decay on the diameter classes, correlated with damage frequency (%) and development stage, it is presented in figure 2.

Discussions and conclusions

Putting into a table formulas (10) - (12) and (22) - (24) it was obtain the theoretical frequency of the damaged trees number on the diameter classes and theoretical frequency of the affected volume by stem decay on the diameter classes. These two indicators are characteristic elements of the artificial even-aged spruce stands correlated with damage frequencies produces by this biotic disturbance factor.

Theoretical frequencies shown in figures 1 and 2 indicate that growing value of the trees damaged by deer, going to a right shifting of the frequency curves that was flattening. Those became large more and more, with diameters variation amplitude increase of the damaged trees and stands has became more heterogeneous from trees size combination.



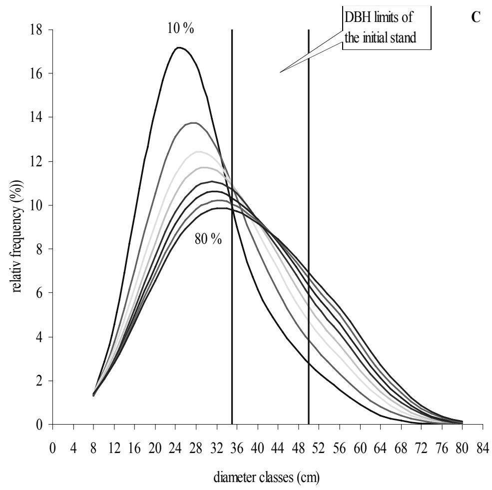


Figure2. Structural model about distribution of the affected volume by stem decay on the diameter classes, correlated with damage frequency (%)
A - Pole stage;
B - Young timber stage;
C - Mature timber stage.

Regression equations (1) - (9), (13) - (21) and frequency functions (10) - (12), (22) - (24) are very important for elaboration the complex mathematic model of the spruce stands, from risk zone to the biotic and no biotic disturbance factors (wind, snow, deer). They allow automatic data processing for elaboration optimal structure models correlated with ecological, economical and social functions, especially for stands and for the whole forest.

More than that, knowledge of the spruce stands structure, like distribution of the tree damaged by deer on the diameter classes and like distribution of the volume affected by stem decay on the diameter classes, are very important in establishing the dimensional assortments dynamic correlated with stand age, development stage and with qualitative characteristics of the spruce stands damage by deer (damages frequency, average age of damages, percent of the stem decay).

Also, in execution of the silvicultural operations from each development stage, it can be stipulate to witch diameter classes should be interfere for reducing the damage frequency, finally for a better spruce stands quality and stability. It is possible to establish a prognosis model taken care about actual conditions, probability of the stand structure evolution, correlated with influence of the disturbance factors from research area (wind, snow and deer). These, correlated with the probability, possibility and necessity of the silvicultural operations execution from each development stage, could be considered as ground basis elements for making computer assisted decision about middle and long term sustainable forest management in mountains ecosystems affected by biotic disturbances factors.

References

ALEXE, A., MILESCU, I., 1983. Inventarierea padurilor. Editura Ceres, Bucuresti. 491 p.

BARTELNIK, H. H., 2000. A growth model for mixed forest stands. Forest Ecology and Management, 134, pp. 29-43.

CHERTOV et al., 1999. A combined simulation model of Scots pine, Norway spruce and Silver birch ecosystems in the European boreal zone. Forest Ecology and Management, 116, pp. 189-206.

GIURGIU, V., 1972. Metode ale statisticii matematice aplicate în silvicultura. Editura Ceres, Bucuresti566 p.

GIURGIU, V., 1978: Conservarea padurilor. Editura Ceres, Bucuresti. 308 p.

GIURGIU, V., 1979: Dendrometrie si auxologie forestiera. Editura Ceres, Bucuresti. 692 p.

GRABER, D., 1994: Die fichtenkernfaule in der nordschweiz: schadenausmass okologischezusammenhange und waldbaulich massnahmen. Journal forestier Suisse, nr. 11, pp. 905 - 925.

HANEWINKEL, M., PRETZSCH, H., 2000. Modelling the conversion from even-aged to uneven-aged stands of Norway spruce (Picea abiesL. Karst.) with a distance-dependent growth simulator. Forest Ecology and Management, 134, pp. 55-70.

ICHIM, R., 1975. Cercetari asupra calitatii lemnului în arboretele de molid din nordul tarii. Manuscris. I.C.A.S. Bucuresti. 46 p.

ICHIM, R., 1990. Gospodarirea rationala pe baze ecologice a padurilor de molid. Editura Ceres, Bucuresti. 186 p.

KOLSTRÖM, T., 1993. Modelling the development of an uneven-aged stand of Picea abies. Scandinavian Journal of Forest Research 8, pp. 373-383.

LÄHDE, E., et al., 1994. Structure and yield of all-sized and even-sized Scots pine-dominated stands, Annual Science Forest 51, pp. 111-120.

LEAHU, I., 1994. Dendrometrie. Editura didactica si pedagogica Bucuresti. 374 p.

PORTÉ, A., BARTELNIK, H. H., 2002. Modeling mixed forest growth: a review of models for forest management. Ecological modelling 150, pp. 141-188.

PRETZSCH, H., 1997. Analysis and modeling of spatial stand structures. Methodological considerations based on mixed beech-larch stands in Lower Saxony. Forest Ecology and Management, 97, pp. 237-253.

VLAD, R., 2002a. Fundamente stiintifice auxologice si amenajistice privind gestionarea padurilor de molid din nordul tarii vatamate de cervide. Teza de doctorat, Universitatea “Stefan cel Mare” Suceava.

*** Ministry of Forest Resources Inventory Branch Victoria, BC, 1999: Adjusting tree, volume, decay, and waste estimates in British Columbia. 9 p.