Study on propagation techniques and population structure of *Boswellia papyrifera* (Del.) Hochst in North Gondar Zone

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Abstract
This research has been designed with the purpose to investigate the current population structure of Boswellia stands, examine the possibility of raising stock plants from mature trees of Boswellia papyrifera; to determine the best length, diameter and planting time of cuttings for successful establishment. The study was conducted in North Gondar, Ethiopia. Specifically the population structure study conducted at three woredas, namely Armachiho, Metema and Quarra. Where as the artificial propagation study from cuttings was done at Metema only. To study population structure from stem diameter size distribution, inventory of representative forests was done. For this purpose sample plots measuring 20x20 m^2 were used for inventory. Sample plots have been laid on transect lines stretched along the slope. Moreover, cuttings were taken from branches of healthy looking trees. The branches were taken during the time of planting and pit preparation. Each branch cutting was planted in a pit that has a 50 cm depth and a cross section area of 900m^2. The experimental design was a factorial arrangement of three levels of length of the branch cutting (1 m, 1.5 m and 2 m), two levels of cutting diameter(10-15 cm, 16-20 cm and 21-25 cm), and four levels of planting season (first week of May, second week of July, third week of October, and third week of March). In each plot, 7 branch cuttings were planted in raw at a spacing of 2 m and 4 m spacing has been used for between rows. Data were analyzed using the General Linear Model (GLM) procedures of SAS (2000). The result showed most of the sites have tree densities of between 200 and 300 individuals trees with DBH > 10 cm per ha. Moreover all sites studied showed a similar hump shaped distribution. The hump shaped curves overestimated the frequency of the small individuals in the populations and underestimated the large individuals. In most populations the number of small individuals was extremely low, suggesting a lack of regeneration. The cutting trial also showed that among the treatments, planting season and its interaction with the height of the cutting found to bring significant difference.

Key words: Boswellia papyrifera, Population structure, propagation techniques, Metema

1. Introduction

Boswellia papyrifera (Del.) Hochst. is an oleo-gum resin producing, deciduous multipurpose tree species with a paperacious bark that peels in flakes. It is one of the 17 genera described in the family *Burseraceae*, which is estimated to encompass about 500-600 species (Vollesen, 1989; Hedberg and Edwards, 1989). It is found in woodlands and wooded grass lands, on steep rocky slopes, lava flows or sandy river valleys, at an altitude between 950 - 1800m a.s.l. and with an annual mean temperature of 20-25^{o} C and an annual mean precipitation of less than 900 mm (Von Breitenbach, 1963; Anonymous, 1997, Azene, 1993; Fitchel and Admassu, 1994).

Boswellia has an immense ecological and economic significance (Azene, 1993). It is found to be highly suitable for future reforestation establishments or restoration efforts in moisture deficit arid and semi arid areas (Kindeya et al., 2005). This species produces frankincense, an oleo-gum resin valued for its industrial, folk medicine, cultural and religious uses (Girmay, 2000). It has wide demand in domestic and international markets.

In ANRS, the woodlands dominated by B. papyrifera is identified in nine zones covering 34 woredas and 151 PAS. The total area covered by Boswellia stand is estimated to be over 600,000 ha (Girmay, 2000; Anonymous, 1997) and was observed in the lowland areas of the Nile and Tekeze basins and the western lowlands. According to the Regional Bureau of Agriculture (Anonymous, 1997), about the 69.4 % (419,216 ha) of the Boswellia stand occur in North Gondar Zone (NGZ) where it is found abundantly in Metema, Quara and Armacheo woredas of NGZ. If the resource is managed properly a wide range of various benefits could be obtained as creation of new employment, new industries, foreign exchange as well as land conservation and rehabilitation.

Ethiopia is one of the world's largest producers of Frankincense (olibanum), the exploitation of olibanum is one of the top income and employment generating activities in North Gondar and therefore a very important source of revenue for the country and the rural people (Mulugeta, et al. 2003). Due to this exploitation the potential range of forest communities with Boswellia is greatly reduced and is classified as an endangered species (Kindeya et al., 2002; NCSS, 1993). A major concern is the missing or hampered natural regeneration and the increased vulnerability to pests and other damages caused by tapping (Ougbazghi, 2001, Tilahun, 1997; Marshall, 1998; Kindeya et al 2002). In response to this challenge tree population structure and propagation by cutting studies has been conducted in North Gondar, Ethiopia. Hence, this research has been designed with the purpose to investigate the current population structure of Boswellia stands, examine the possibility of raising stock plants from mature trees of *Boswellia papyrifera*; to determine the best length, diameter and planting time of cuttings for successful establishment.

2. Materials and methods

The study area

The study was conducted in North Gondar, Ethiopia. Specifically the population structure study conducted at three woredas, namely Armachiho, Metema and Quarra. Where as the artificial propagation study from cuttings was done at Metema only.

Tree population structure study

To study population structure from stem diameter size distribution, inventory of representative forests was done. For this purpose sample plots measuring 20x20 m^2 were used for inventory. Sample plots have been laid on transect lines stretched along the slope.

Study of artificial propagation from cutting

In order to study artificial propagation from cuttings, cuttings were taken from branches of healthy looking trees. The branches were taken during the time of planting and pit preparation. Each branch cutting was planted in a pit that has a 50 cm depth and a cross section area of 900m^2. The thick end of branch cuttings that would be buried in the ground has been cut slant to increase the exposure of the surface areas of the cambial layer. The cutting was placed in the pit in an oblique manner so that the slant cut lower end will get maximum contact with the pit. After planting the cuttings, a thorough ramming of the fine earth was done to eliminate air voids.

Experimental design and data analysis

a. population structure

From the inventory result, the total population was summarized with a table of frequency, where the first column represents the diameter class and the second the total number of trees per hectare with in that diameter class. The diameter class was divided into two cm. The stem diameter size distributions obtained in this way have been used to fit in to Weibull distribution curves.

$F(x) = 1 - e^{-(x/\beta)\alpha}$

This distribution is characterized by the distribution function F(x), the number of trees at DBH class x, the scale parameter β, the slope parameter α, and the DBH(x) in cm. This function is very successful in fitting stem-size distribution data (Bailey & Dell 1973, Alder 1995; Vanclay, 1994) and is popular with modelers dealing with uneven-age stands (Hyink & Moser 1979; Kamziah et al. 2000; Zhang et al, 2001). Most forms of the distribution show either a simple decline or a unimodal form. Depending on the shape parameters, the distribution is skewed to the left, symmetrical, or skewed to the right. The scale parameter (β) is approximately equal to the median DBH while the shape parameter controls the skewness of the distribution. When the shape parameter becomes less than 1 the curve approaches an inverse J-shape distribution. Model parameters were determined by means of linear regression and maximum likelihood methods (Sheil and Salim, 2004). The disparity between the observed and the predicted distribution and between sites was explained by the responsible ecological factors (Lykke, 1998; Swaine, 1998).

b. Study of artificial propagation from cutting

The experimental design was a factorial arrangement of three levels of length of the branch cutting (1 m, 1.5 m and 2 m), two levels of cutting diameter(10-15 cm, 16-20 cm and 21-25 cm), and four levels of planting season (first week of May, second week of July, third week of October, and third week of March). In each plot, 7 branch cuttings were planted in raw at a spacing of 2 m and 4 m spacing has been used for between rows. The following model has been used for data analysis

Y=m+B+L+D+S+(S*H)+eijk

Where
M=the overall mean
B= block
H= length of cutting
S= planting season
S*H= interaction of season and the length of the cutting

Data were analyzed using the General Linear Model (GLM) procedures of SAS (2000). When there were no interactions and terms that were not significant in the full model, the reduced model was employed for analysis. The terms indicating the effects of diameter and its interaction with season of planting and cutting length were not included in the statistical analysis.

3. Results

Population Status

tree densities of between 100 and 300 individuals trees with DBH > 10 cm per ha with the exception of Zewdie Badema, Gelealewan and Yiergaminch with only 65, 92 and 54 individuals per ha respectively.

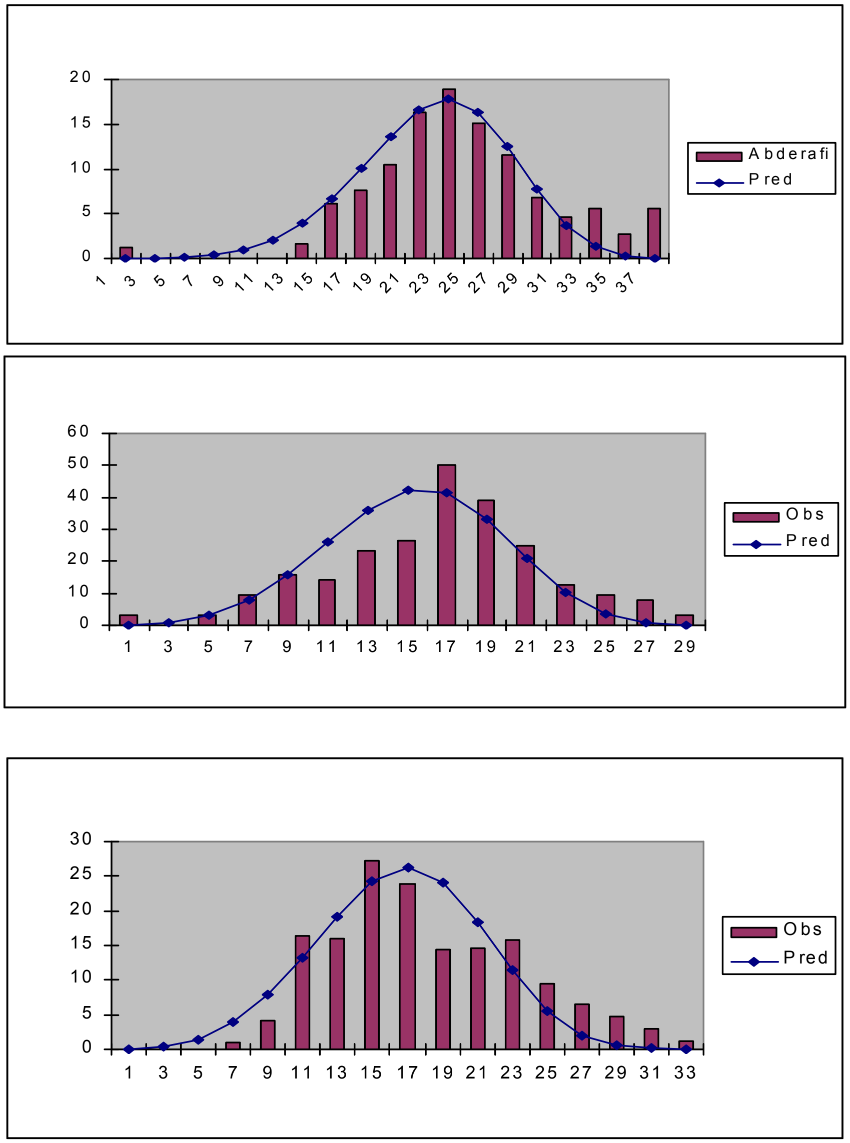

Fig 1 Population structure of *Boswellia papyrifera* in the three study sites

All sites studied showed a similar hump shaped distribution (Figure1). The hump shaped curves overestimated the frequency of the small individuals in the populations and underestimated the large individuals. In most populations the number of small individuals was extremely low, suggesting a lack of regeneration.

Cutting survivals

The GLM analysis of the SAS showed that, among the treatments, planting season and its interaction with the height of the cutting found to bring significant difference. Cutting size doesn't show correlation with the planting season.

Table 2. Model ANOVA

Source	DF	SS	MS	F Value	Pr > F
Model	15	142.1635860	9.4775724	3.70	<.0001
Error	71	182.0591704	2.5642137		
Corrected Total	86	324.2227564			

R-Square	CV	Root MSE	Mean
0.438475	22.57923	1.601316	7.091988

Table 3. ANOVA of season, diameter and height

Source	DF	SS	Mean Square	F Value	Pr > F
Block	3	22.28049321	7.42683107	2.90	0.0410
Season	3	72.21816491	24.07272164	9.39	<.0001
Diameter	1	0.82067623	0.82067623	0.32	0.5734
Height	2	8.33657055	4.16828527	1.63	0.2040
Season*Height	6	38.50768113	6.41794686	2.50	0.0297

Table 4. Least square mean and the probability values

Season	Height	LSMEAN	Standard Error	Pr > |t|
1	1	4.29324900	0.94618859	<.0001
1	2	5.83479812	0.66193478	<.0001
1	3	6.03599312	0.60725933	<.0001
2	1	6.64741830	0.56615078	<.0001
2	2	7.21377412	0.56615078	<.0001
2	3	8.22845633	0.56615078	<.0001
3	1	7.38496766	0.56615078	<.0001
3	2	8.58983185	0.56615078	<.0001
3	3	8.80102044	0.56615078	<.0001
4	1	7.94271541	0.60735196	<.0001
4	2	5.61197642	0.56615078	<.0001
4	3	6.45172079	0.56615078	<.0001

From the analysis of the cutting survival, it was observed that larger diameter has got the highest value in terms of survival (~51.06%). Smaller diameter branches showed lower survival rate (~47.32%). The survival value of (~57.14%) was observed for lager height size cuttings and medium and smaller height size showed lower survival rate, (~47.32%) and (~42.41%) respectively. Seasons showed much difference in terms of survival of cuttings was observed. Those cuttings planted on March and May showed the survival rate of (~57.14%) and (~70.83%) respectively. The poor survival rate was observed for October and July planting season which is equivalent to (~22.02%) and (~45.83%) respectively.

The GLM analysis of the SAS showed planting of cuttings at planting season of three is the best as compared to other planting seasons. Larger size of cuttings also most favorable for better survival of cuttings at any diameter class

Discussion

Population structure

The number of mature trees per hectare varied from 200 to 300. The most abundant family was *Fabacaea* and the most abundant species were*: Acacia etbaica (17 - 44 trees/ha), Lannea fruticos (7 – 10 trees/ha), Terminalia brownie (4 – 16 trees/ha), Combretum hartmannianu (2 trees/ha) and Ximenia americana (2 trees/ha).*

The most striking result from the stem diameter size distributions of *B. papyrifera* in all the study sites is the under-representation of individuals in the lower diameter classes and the over-representation of individuals in the higher diameter classes. More than half (~ 65 %) of the total population of *B. papyrifera* is in the range of 16 – 24 cm and 13 – 15 cm DBH respectively. The extremely low density of individuals in the lower diameter classes suggests that recent regeneration is severely lacking and that the population is under serious threat on the long run.

Should the observed regeneration structures in *B. papyrifera* raise the alert level? It should indeed, if regeneration indeed is lacking. However, it is still possible that the populations are in a steady state condition, as it occurs in many dry types of woodland. In some Acacia woodlands, for instance, very few individuals can sufficiently replace the standing vegetation without negatively affecting the viability of the population (Ashkenazi, 1995; Wiegand, et al. 1999). In many cases, however, population structures as shown by *Boswellia* indeed indicate lack of regeneration. Dynamic, monitoring studies are highly needed to be sure about this.

A lack of regeneration can be caused by a number of factors. First we have to distinguish between regeneration via seeds or via root suckers. If via seeds, several steps can lead to reduced regeneration. Trees may not produce sufficient seeds. Seeds may not be viable, due to seed quality (e.g. lack of embryo) or to high seed infestation by insects already on the mother tree. Once on the ground, seeds may not be able to further disperse because they are highly infested by insects and/or eaten by vertebrate herbivores and destroyed. Germination may be hampered by sub-optimal environmental conditions (too cold, too dry). Once germinated, the resulting seedlings may be trampled or eaten by grazers, or show very low growth rates due to low light availability, low water or nutrient availability. Also seedlings may be susceptible for herbivorous insects, or fungi. The alternative route of regeneration is via root suckers. In the following we treat most of these possibilities for the case of Boswellia.

There is no agreement on the origin of the observed seedling and sapling populations in different areas. Bond and Midgley (2001) distinguished two modes of regeneration: recruitment by means of seeds and persistence by means of root sprouting. Root sprouting is thought to be the preferred mode of regeneration in frequently disturbed environments. For *B. papyrifera* both seedlings reproduced sexually from seed and asexually from root suckers are found (Ogbazghi, 2001; Abeje, 2002, Yitebitu & Mengistie, 2005). However, the main route of regeneration is variable. Some studies reported root suckers as the main route of regeneration (Yitebitu & Mengistie, 2005) while others found sexually produced seedlings to be the main route of regeneration (Ogbazghi, 2001; Abeje, 2002).

In view of the seed properties of this species, such as absence of a soil seed bank reserve (Abeje, 2002), absence of seed dormancy (Tilahun and Legesse, 1999), the susceptibility of the seeds to insect attack and the production of non-viable and embryo-lacking seed (Ogbazghi, 2001), regeneration from root suckers as a main route of regeneration is a sensible speculation. This is substantiated, though not strongly quantified, by several authors and personal communications. However, there is not enough information on either the origin of observed seedlings (either from seed or roots sucker) or the differential performance of these seedling groups. We hypothesize that seedlings from root sucker origin may perform better as we expect these seedlings to be continuously nursed by the mother tree for moisture and nutrients.

Cuttings

This study in general reveled that diameter size has not strong impact on the survival of *Boswellia papyrifera* from cuttings rather cutting heights showed strong correlation with survival. This study also identified the best planting season for *B. papyrifera* cuttings. High survival rate was observed for planting seasons of three and four. This may be due short drought period for cuttings.

Conclusion and Recommendation

The present study showed *Boswellia* is one of the denser tree species in the study sites. The tree is actually represented in adult trees where main production and reproduction of the tree rely. The smaller sizes or seedlings are absent or few in the study sites indicating the regeneration status of the tree is severely limited. This extremely low density of individuals in the lower diameter classes suggests that recent regeneration is severely lacking and that the population is under serious threat in the long term. Of those factors contributed, the conversion to agriculture land contributes more for the degradation of the Boswellia woodland. Generally two theories have been forwarded in connection with the rapid transformation of the *Boswellia* woodland to agricultural lands in the Amhara Region. These are the institutional weakness and denial of involvement of local people to participate fully in the management and utilization of the resource and the existence of better economic returns from other pending land use. These both may offer no incentive to conservation of the *B. papyrifera* woodlands, rather, they instigates clearance of the woodlands and their conversion to other forms of land use, because this is a better option for the local people to benefit from the land resources. Generally, efforts should be made to conserve the resource base (co-management) and to increase the socio-economic importance of the tree by reconsidering the regulations that permit the collection and marketing of incense through license. Most interestingly the result of this study indicated that it was possible to get better survival of *Boswellia papyrifera* from cuttings, however there is a need for further investigation of this result in the field condition to facilitate the development and rehabilitation of *Boswellia* stands in the study sites so as to be able to reap multiple benefits from this resource base.

Reference:

Abeje Eshete (2002). Regeneration Status, Soil Seed Banks and Socio-Economic Importance of B. papyrifera in Two Woredas of North Gonder Zone, Northern Ethiopia. MSc thesis, Swedish University of Agricultural Sciences, MSc thesis, Skinnskatteberg, Sweden.

Alder, D. (1995). Growth modelling for mixed tropical forests. Tropical forestry paper 30. Oxford Forestry Institute, Oxford, England.

Anonymous (1997). Technical Manual for the Development/Propagation and Production of Incense Resource Base. Amhara National Regional State, Bahar Dar (unpublished).

Ashkenazi, S. (1995) Acacia trees in the Negev and the Arava, Israel: A review following reported large-scale mortality. Hakeren Hakayemet LeIsrael, Jerusalem (in Hebrew, with English summary).

Azene, Bekele-Tesemma, Birnie, A. and Tengnas, B. (1993). Useful Trees and Shrubs for Ethiopia. Identification, Propagation and Management for Agricultural and Pastoral Communities. Regional Soil Conservation Unit, SIDA, Nairobi.

Bailey, R.L., and Dell, T.R. (1973). Quantifying diameter distributions with the Weibull function. For. Sci. 19: 97–104.

Bond W. J. & Midgley J. J. (2001). Ecology of sprouting in woody plants: the persistence niche. *Trends in Ecology and Evolution 16: 45–51.*

Fichtl, R. and Admasu Adi (1994). Honeybee Flora of Ethiopia. Margraf Verlag, Weikersheim.

Girmay Fitwi (2000). The status of gum arabic and resins in Ethiopia. Report of the Meeting of the Network for Natural Gum and Resins in Africa (NGARA) 29th-31st May, Nairobi, Kenya. pp. 14-22.

Hedberg, I., Edwards, S. (eds.), (1989). Flora of Ethiopia, Volume 3 Pittosporaceae to Araliaceae. The National Herbarium, Addis Ababa University, Addis Ababa, Ethiopia. 659 pp.

Hynk, D. M., AND J. W. Moser. (1979). Application of diameter distribution for yield projection in uneven-aged forests. In W. E. Frayer (Ed.). Forest resources inventories, pp. 906–916. Proc. SAF/IUFRO Workshop, Colorado State University, Fort Collins, Colorado.

Kamziah A. K., M. I. Ahmad, AND Y. Ahmad Zuhaidi. (2000). Modelling diameter distribution in even-aged and uneven-aged forest stands. J. Trop. For. Sci. 12: 669–681.

Kindeya G., Muys, B., Mitiku H., Mitloehner, R., (2002) Boswellia papyrifera (Del.) Hochst.: a tropical key species in northern Ethiopia. Paper presented at the Conference on International Agricultural Research for Development, Deutscher Tropentag 2002, Witzenhausen, October 9-11, 2002, Germany. 8 pp.

Kindeya Gebrehiwot, B. Muys, M. Haile and R. Mitloehner (2005). The use of plant water relations to characterize tree species and sites in the drylands of northern Ethiopia. Journal of Arid Environments. Vol 60(4) 581-592

Lykke, A.M., (1998). Assessment of species composition change in savanna vegetation by means of woody plants' size class distributions and local information. Biodiversity and Conservation 7: 1261-1275.

Marshall, N., (1998). Searching for a cure: Conservation of medicinal wildlife resources in East and Southern Africa. A Species Endangered Report, September 1998, Nairobi, Kenya. 12 pp.

Mulugeta Lemenih and Demel Teketay (2003). Frankincense and Myrrh: Distribution, Production, Local Uses, Development Potential, Medicinal and Industrial Uses, and Research Needs in Ethiopia. *SINET: ETHIOP. J. SCI*., 26(1):63–72

NCSS (National Conservation Strategy Secretariat) (1993). National Conservation Strategy, Vol.1: National Policy on the Resources Base, its Utilization and Planning for Sustainability. NCSS, Addis Ababa, Ethiopia.

Swaine, A.M., (1998). Assessment of species composition change in savannah vegetation by means of woody plants' size class distribution and local information. Biodiversity and conservation 7: 1261-1275.

Tilahun Gebremedhin (1997). Boswellia papyrifera (Del.) Hochst. from Western Tigray. Opportunities, Constraints and Seed Germination Responses. MSc. thesis, Swedish University of Agricultural Sciences, Skinnskatteberg.

Tilahun Gebremedhin and Legesse Negash (1999). The effect of different pre sowing seed treatments on the germination of Boswellia papyrifera, a key dry land tree. Ethiopian Journal of Natural Resources 1: 57-75.

Vanclay, J.K. (1994). Modelling forest growth and yield. Application to mixed tropical forests. CAB International. UK. 312 pp

Vollesen, K. (1989). Burseraceae. In I. Hedberg and S. Edwards (eds.), Flora of Ethiopia, Volume 3. National Herbarium, Addis Abeba University, Addis Abeba and Uppsala University, Uppsala. pp. 442-478.

Von Breitenbach, F. (1963). The Indigenous Trees of Ethiopia. Ethiopian Forestry Association, Addis Abeba.

White, F., (1983). The vegetation of Africa: A descriptive memoir to accompany the UNESCO/AETFAT/UNSO, Vegetation map of Africa. United Nations, UNESCO, Switzerland. 356 pp

Wiegand, K., F. Jeltsch, and D. Ward. (1999), Analysis of the population dynamics of Acacia trees in the Negev desert, Israel, with a spatially-explicit computer simulation model: Ecol. Model. 117: 203–224.

Woldesellasie Ogbazghi, (2001). The distribution and regeneration of Boswellia papyrifera (Del.) Hochst. in Eritrea. PhD Thesis. Tropical Resource Management Papers No. 35, Wageningen University, The Netherlands. 131 pp.

Yitebitu and Mengistie (2005). Effects of fencing and ground cultivation on natural regeneration of Boswellia papyrifera in Metema Wereda, Ethiopia. Sympossium on the rehabilitation of dry land forest: Ecology and Management, September 23-24, 2004, Mekelle, Ethiopia.

Zhang, L., Jeffrey H. Gove, Chuangmin Liu, and William B. Leak. (2001). A finite mixture of two Weibull distributions for modeling the diameter distributions of rotated sigmoid, uneven-aged stands. Can. J. For. Res. 31: 1654–1659 .