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Optimum Structures of Black Sea Region Fir Forests

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Abstract

It is known that fir, being a shade-tolerant tree species, form selection forests which have naturally self-specific increment and growth laws. Because of that they are managed as even-aged forests or in the direction of allowable cut formulas which are not suitable to its natural structure, their optimum structures and ecosystems of these forests being spoiled. With the applied management form contrary to the concept of today's sustainable forestry, these fir forests are managed at a level of very small increment. Whereas, if they are managed as selection forest, both its ecosystem improvement and sustainability will be provided and a contribution will be made to the economy of the country, running them with an increment potential equal to or more than 13 m^3/ha. In this paper, the information about increment and growth laws which provide posibilities to manage the Black Sea Region fir forests as selection forests will be given.

Key words: Black Sea Region, fir, selection forest, uneven-aged forest, site index

Introductıon

Shade-tolerant fir trees can naturally build even-aged or uneven-aged stands. But, both stand types also indicate selection structure. Even-aged fir stands that naturally occur after various disturbances, yet gradually transform into uneven-aged stand form if not disturbed from the beginning of destruction period when mature trees naturally die-off from the stand. Management of uneven-aged fir stands as light-tolerant, single-layered even-aged stands is not appropriate to their inherent structures and causes them to produce a lower increment. Even in the case when fir forests are managed towards selection forest with the today's management techniques, it is impossible to take them to the optimum structure that maximizes the volume increment and hence their inherent structures retrograde.

The management techniques developed for uneven-aged fir forests up to today are disadvantageous to use, because they are based on various wrong assumptions and do not take into account the inherent dynamic structures of fir forests in the calculation of allowable cut. The fir stands in Turkey are seen to gradually diverged from the optimum structure as the result of silvicultural treatments applied according to the **Hufnagel's** diameter class method currently in use. The reason of this is that **Hufnagel's** formula gives an allowable cut without depending on the optimum structure for the diameter classes unnecessary to touch (Eraslan, 1982; Kapucu, 2004).

Basing the allowable cut determination on all positive deviations from the optimum structure curve is also a wrong application. Without knowing the diameter growth speeds of trees in various diameter classes, it is not possible to determine the allowable cut depending on only the mean transition times of diameter classes (Eraslan, 1982). As the mean age of a fir stand can not be calculated with increment cores taken from a few fir trees, the mean transition times of diameter classes can not also be truely determined, because the growth potentials of fir trees growing under the crown and side suppressions are so different (Saraçoğlu, 1988). Even if determined, their application to the diameters in a diameter class completely different from each other does not conform to dynamic structures of fir stands. Hufnagel's diameter class method is also inconsistent in respect to the assumption on which it is based. According to this assumption, the trees in a diameter class completely transfer to the next one in the transition time of that diameter class. However, the transition time is a mean value and only some of trees can pass into the next class in this time. It is wrong to think that all trees pass into the upper class. Also the diameter increments of trees in a diameter class are so different from each other since they have different diameters. As a result of this, when the smallest diameter trees in a class passes into the next class, the diameters of that class spread into a much wider interval than the original diameter class width. Herewith, the number of trees in the next diameter class becomes lower. Hufnagel's diameter class method is inconsistent since it assumes that the number of trees in the mentioned class does not decrease.

In this paper, it has been aimed to bring suitable solutions to the structures of uneven-aged or selection forests since wrong applications continue.

Material and Method

The information given here are based on the findings of a Forest Yield Study research carried out depending on the data collected from 77 temporary plots located in the Black Sea Region uneven-aged fir forests in the years 1979–1982 (Saraçoğlu, 1988). In the research, the fir trees growing in the east and west Black Sea Regions of Turkey were treated as one species, because they did not show any difference from the point of view of increment and growth (Miraboğlu, 1955). The data were evaluated by the programs written in FORTRAN 77 programming language in the Haydar Furgaç Computer Center of İstanbul University in Turkey. In the study, the structures of uneven-aged fir stands and many statistical relationships of these stands were investigated then a program named MAXART was written using the deterministic simulation method depending on the knowledge and relationships obtained from this investigation. The program MAXART finds the optimum structures that maximize the volume increment per hectare in these fir stands. When the program is computer run, only stand site quality index and goal diameter are used as input. The program first generates the diameter at breast height for the beginning and the end of a 10-year period, using the probability density function of fir stands and computes the volumes and volume increments for each fir tree existing per hectare. The probability density function is generated from the diameter distribution curve equation which depends on stand site quality index and density degree. Later, it determines the optimum stand structure which gives a total maximum periodic volume increment, approaching to it as aimed by successively changing the stand density degree.

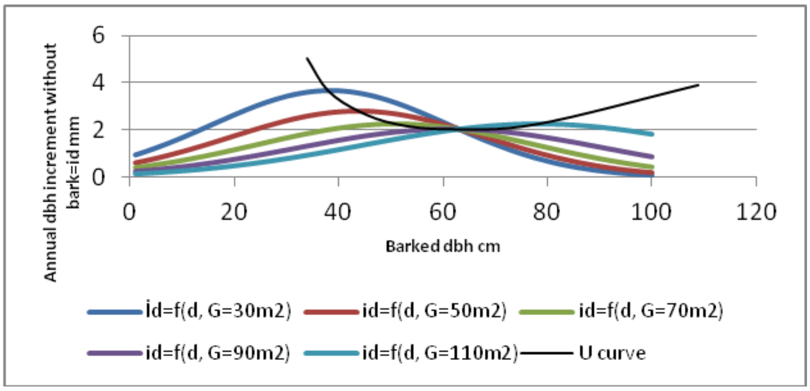
Findings

The relationship between diameter and diameter increment gives dynamism to the structures of uneven-aged fir forests, but its determination is very difficult because it requires a large number of data. The diameter increments of trees change in a wide range because of very unstable climatic conditions and neighbourhood relationships amongst trees. This range is rather affected by stand density thereby stand basal area more than site quality. In order to find the diameter increment relationship, the diameters and diameter increments of 1,358 sample trees taken from the sample plots were measured and separated into two groups according to that the basal areas of the stands where they existed are smaller or bigger than 55 sq.m/ha. Each group of the points was plotted on the same graph using different marks. The distribution of the points on the graph generally represented a bell-shaped distribution; the majority of the points which have a stand basal area bigger than 55 sq.m/ha came down the graph. This situation testified that diameter increment relates to stand basal area or stand density.

The bell-shaped distribution of the points had confirmed the findings of Prodan (1965, p. 483) and Kalıpsız (1968). So, the relationship among the variables diameter (dbh, cm), basal area (G, m^2/ha) and diameter increment (i_d, cm) were determined as the regression equation:

$$\boxed{\hat{i}_d = \exp\left[\left(0{,}5429 + 0{,}076047d - 0{,}0011651d^2 - \left(0{,}022395 + 0{,}000057726d - 0{,}0000065379d^2\right)G\right)\right]}$$

The correlation coefficient R=0.54461*** was found significant with a confidence level of 0.001. The reason of that the correlation coefficient is small may be depended on very different suppression degrees of trees (Saraçoğlu, 1988). The curves represented by the above relationship have been showed in Figure 1 for different basal area values.



Figure–1. Diameter-diameter increment curves corresponding to different basal areas.

The figure shows that as long as basal area increases, the top points of the bell curves draw a U curve, first come down and then rise up after the lowest point of the U curve sliping to the positive direction of the x axis. This means that as long as the stand density degree or basal area in an uneven-aged forest increases, the diameter increments of thick-diameter trees become bigger than those of thin-diameter trees. The bell curves rising upward after about 65 cm dbh are counted to be an index of site quality, since the increase of site quality causes the increase of basal area in uneven-aged forests contrary to the even-aged forests. These findings completely conform to the Mitscherlich's (1952) site quality determination of uneven-aged stands using dbh increments and the numbers of trees per hectare of thick-diameter trees. The diameter increment relationship determined above is very important since it accounts for how uneven-aged stands behave during the growth. According to this, it is possible to slide big diameter increments to the desired diameter classes by changing basal area. But there is a single basal area for which stand volume increment becomes maximal.

The diameter increment relationship also accounts for how the diameter growth speeds of trees change from one diameter class to another. According to this, the trees in diameters encountering to the first inflection point of diameter increment curve will have the fastest diameter growth while the trees in diameters encountering to the second inflection point of the curve have the slowest diameter growth. The diameter growth speeds of trees increase up to the first inflection point and then decrease up to the second inflection point (Figure 2 b and c). The lengths of the arrows in Figure 2b represent the speeds of tree diameter growth. Therefore, the first inflection point was named as “Escape Point or Thinning Center” (d_A) and also the second inflection point as “Thickening or Aggregation Center” (d_B) (Figure 2). In such a position, the trees with smaller diameter than the diameter encountering to the top point of the diameter increment curve should not be removed from the stand during tending cuttings if possible**.** The best is to use the number of trees and volume to be removed from each diameter class in the stands of optimum structure from the yield tables provided by the MAXART programme (Table 1). In these tables, the numbers of trees, basal areas and volumes in diameter classes were given for the beginning and the end of a 10-year period (columns 2–7). The values at the beginning of the period belong to the optimum structure of the given site quality degree (BOD), the target diameter and the optimum density coefficient (OSK).

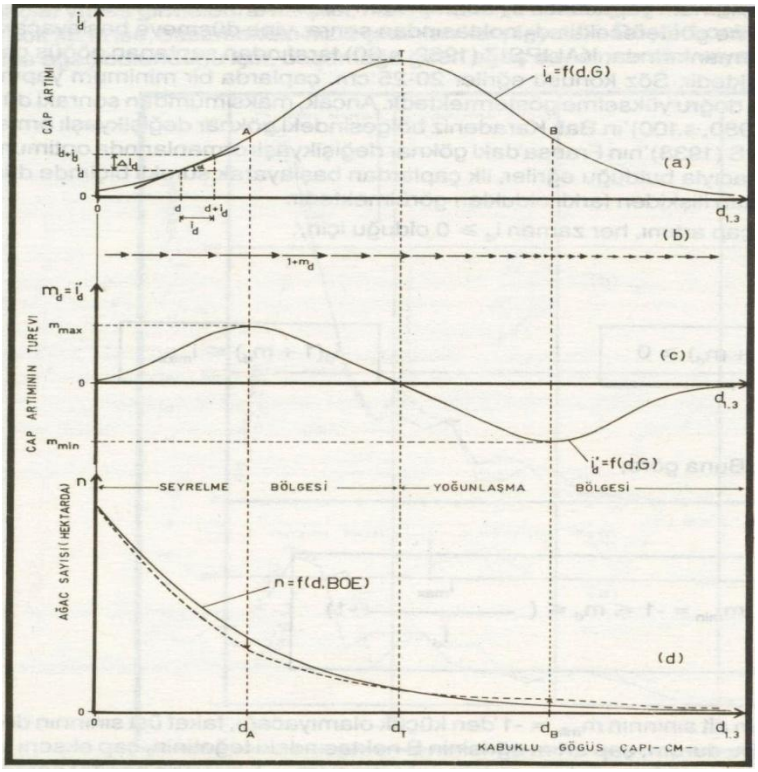
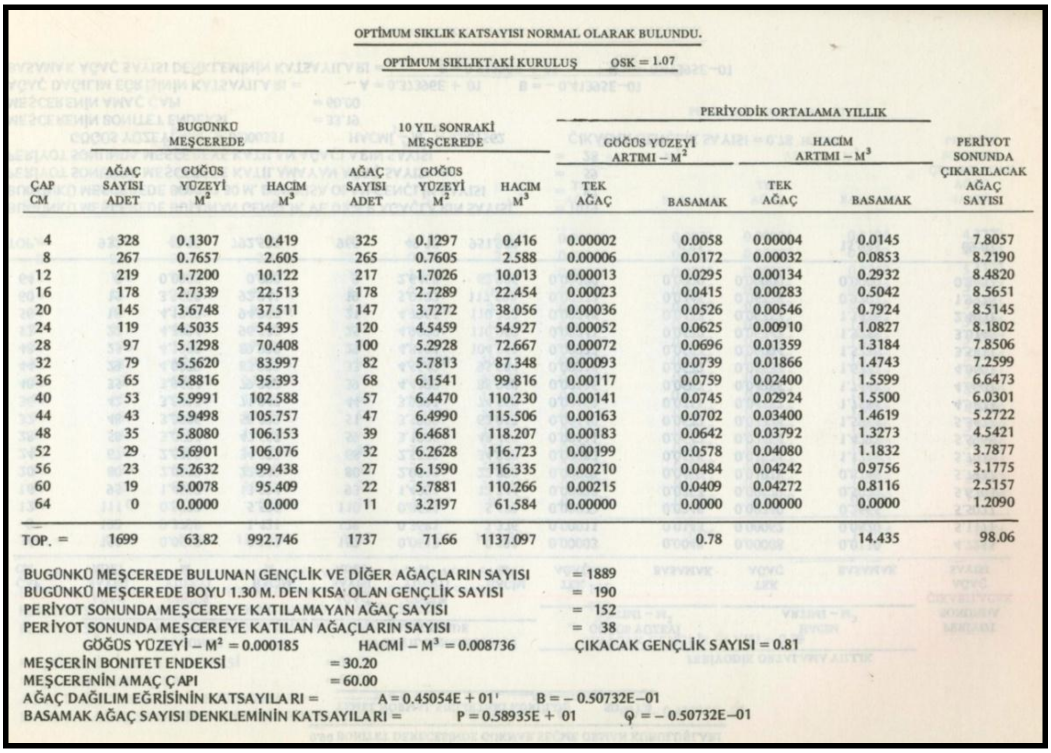


Figure-2. The effect of the diameter-diameter increment relationship {i_d=f(d, G)} to the diameter growth speeds of trees and the optimum structure of stand {n=f(d, BOE)}.
(ÇAP ARTIMI=Diameter increment (i_d), ÇAP ARTIMININ TÜREVİ=The derivative of diameter increment (i_d'), AĞAÇ SAYISI (HEKTARDA) = The number of trees per hectare, KABUKLU GÖĞÜS ÇAPI=The dbh outside bark, SEYRELME BÖLGESİ = Thinning region, YOĞUNLASMA BÖLGESİ = Agregation region, d=dbh, G=Basal area per hectare, i_d = Diameter increment, BOE=Site quality index)

Table 1. The original output of the program MAXART for BOD=0.7, target diameter 60 cm and OSK = 1.07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                        OPTİMUM SIKLIK KATSAYISI NORMAL OLARAK BULUNDU.

                          OPTİMUM SIKLIKTAKİ KURULUŞ      OSK = 1.07

                                                                    PERİYODİK ORTALAMA YILLIK
          BUGÜNKÜ                        10 YIL SONRAKİ
         MEŞCEREDE                          MEŞCEREDE            GÖĞÜS YÜZEYİ            HACİM               PERİYOT
                                                                 ARTIMI – M2           ARTIMI – M3          SONUNDA
       AĞAÇ     GÖĞÜS                  AĞAÇ    GÖĞÜS                                                    ÇIKARILACAK
ÇAP   SAYISI   YÜZEYİ     HACIM      SAYISI   YÜZEYİ     HACIM      TEK                 TEK                  AĞAÇ
CM     ADET      M2         M3        ADET      M2         M3       AĞAÇ     BASAMAK    AĞAÇ     BASAMAK     SAYISI

  4     328    0.1307      0.419      325    0.1297      0.416   0.00002    0.0058   0.00004    0.0145      7.8057
  8     267    0.7657      2.605      265    0.7605      2.588   0.00006    0.0172   0.00032    0.0853      8.2190
 12     219    1.7200     10.122      217    1.7026     10.013   0.00013    0.0295   0.00134    0.2932      8.4820
 16     178    2.7339     22.513      178    2.7289     22.454   0.00023    0.0415   0.00283    0.5042      8.5651
 20     145    3.6748     37.511      147    3.7272     38.056   0.00036    0.0526   0.00546    0.7924      8.5145
 24     119    4.5035     54.395      120    4.5459     54.927   0.00052    0.0625   0.00910    1.0827      8.1802
 28      97    5.1298     70.408      100    5.2928     72.667   0.00072    0.0696   0.01359    1.3184      7.8506
 32      79    5.5620     83.997       82    5.7813     87.348   0.00093    0.0739   0.01866    1.4743      7.2599
 36      65    5.8816     95.393       68    6.1541     99.816   0.00117    0.0759   0.02400    1.5599      6.6473
 40      53    5.9991    102.588       57    6.4470    110.230   0.00141    0.0745   0.02924    1.5500      6.0301
 44      43    5.9498    105.757       47    6.4990    115.506   0.00163    0.0702   0.03400    1.4619      5.2722
 48      35    5.8080    106.153       39    6.4681    118.207   0.00183    0.0642   0.03792    1.3273      4.5421
 52      29    5.6901    106.076       32    6.2628    116.723   0.00199    0.0578   0.04080    1.1832      3.7877
 56      23    5.2632     99.438       27    6.1590    116.335   0.00210    0.0484   0.04242    0.9756      3.1775
 60      19    5.0078     95.409       22    5.7881    110.266   0.00215    0.0409   0.04272    0.8116      2.5157
 64       0    0.0000      0.000       11    3.2197     61.584   0.00000    0.0000   0.00000    0.0000      1.2090
________________________________________________________________________________________________________________
TOP. =  1699     63.82    992.746     1737     71.66   1137.097                0.78               14.435       98.06

BUGÜNKÜ MEŞCEREDE BULUNAN GENÇLİK VE DİĞER AĞAÇLARIN SAYISI          = 1889
BUGÜNKÜ MEŞCEREDE BOYU 1.30 M. DEN KISA OLAN GENÇLİK SAYISI          =  190
PERİYOT SONUNDA MEŞCEREYE KATILAMAYAN AĞAÇ SAYISI                    =  152
PERİYOT SONUNDA MEŞCEREYE KATILAN AĞAÇLARIN SAYISI                   =   38
      GÖĞÜS YÜZEYİ – M2 = 0.000185        HACMİ – M3 = 0.008736        ÇIKACAK GENÇLİK SAYISI = 0.81
MEŞCERİN BONİTET ENDEKSİ                      = 30.20
MEŞCERENİN AMAÇ ÇAPI                          = 60.00
AĞAÇ DAĞILIM EĞRİSİNİN KATSAYILARI =          A = 0.45054E + 01'       B = – 0.50732E–01
BASAMAK AĞAÇ SAYISI DENKLEMİNİN KATSAYILARI =          P = 0.58935E + 01       Q = – 0.50732E–01
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As for the values at the end of the period, they belong to the structure whose optimality was broken and increment was decreased to a certain degree at the end of the period. In order to help the stand structure return to the optimum structure, the stand increment should be removed. The differences of the values which belong to the beginning and the end of the period give the amounts of the increments that should be removed from the stand at the end of the period in terms of diameter classes and sums (Table 2). Dividing these amounts by 10 is also give the annual increments as shown in Table 1. In case the increments are not removed from the stand, the stand structure will spoil and its increment will decrease gradually. In the Saraçoğlu's study (1988), the values shown in the last five columns of the yield tables arranged for various target diameters, site quality classes and optimum density coefficients must not be used since they were computed according to a wrong assumption (See Table 1). They should be recalculated as shown in the Table 2.

Table 2. The structures at the beginning (optimum) and the end of the period and the periodic increments in the fir selection stand of target diameter of 60 cm, IInd site class *(BOD(1)=Site Quality Degree =0.7, BOE=Site Quality Index=30.20m and OSK= optimum density coefficent=Density Degree= 1.07* (2))

d	At the beginning of the period			At the end of the period			10-year increment		
	n_b	g_b	v_b	n_s	g_s	v_s	Δn	Δg	Δv
2	328	0,1307	0,419	325	0,1297	0,416	-	-	-
6	267	0,7657	2,605	265	0,7605	2,588	-	-	-
10	219	1,7200	10,122	217	1,7026	10,013	-	-	-
14	178	2,7339	22,513	178	2,7289	22,454	-	-	-
18	145	3,6748	37,511	147	3,7272	38,056	2	0,0524	0,545
22	119	4,5035	54,395	120	4,5459	54,927	1	0,0424	0,532
26	97	5,1298	70,408	100	5,2928	72,667	3	0,1630	2,259
30	79	5,5620	83,997	82	5,7813	87,348	3	0,2193	3,351
34	65	5,8816	95,393	68	6,1541	99,816	3	0,2725	4,423
38	53	5,9991	102,588	57	6,4470	110,230	4	0,4479	7,642
42	43	5,9498	105,757	47	6,4990	115,506	4	0,5492	9,749
46	35	5,8080	106,153	39	6,4681	118,207	4	0,6601	12,054
50	29	5,6901	106,076	32	6,2628	116,723	3	0,5727	10,647
54	23	5,2632	99,438	27	6,1590	116,335	4	0,8958	16,897
58	19	5,0078	95,409	22	5,7881	110,266	3	0,7803	14,857
62	0	0,0000	0,000	11	3,2197	61,584	11	3,2197	61,584
Sum	1699	63,8200	992,746	1737	71,6667	1137,097	45	7,8467	144,540

(1) 0,0≤BOD≤1,0, BOD=0,00=Worst site quality degree, BOD=1,0=Best site quality degree.

(2) d = dbh=Diameter class value (cm); n_b, n_s=Number of trees per hectare at the beginning and the end of the period; g_b, g_s = Class basal areas at the beginning and the end of the period (m^2/ha); v_b, v_s=Class volumes at the beginning and the end of the period (m^3/ha); $\Delta n= n_s - n_b$, $\Delta g= g_s - g_b$, $\Delta v= v_s - v_b$

The program MAXART can provide yield tables of optimally structured fir stands for each target diameter within the range 30-100 cm or each target number of trees in the last diameter class within the range 1-10 and 51 site quality degrees of 0, 0.02, 0.04, 0.06, …, 1. In the Saraçoğlu's study, the yield tables were provided only for the target diameters of 40, 50, 60, 70 cm, the target number of trees in last diameter class 6 and the site quality degrees 0.1, 0.3, 0.5, 0.7, and 0.9.

Results and Proposals

Firs are valuable forest trees from the point of aesthetics, wood product and sustainable forest (Kayacık, 1980). They are not suitable to be managed in the form of even-aged forests. Fir forests should absolutely be managed in the form of selection forests which are compatible to their inherent structure. While they are managed, it must be behaved consistent to their dynamic structure imposed by their genetic features.

It is wrong to use the mean volume trees of a stand or diameter classes in the calculation of volume increment for uneven-aged fir stands. Allowable cut must be estimated more directly from the volume increment computed on the base of single trees for even-aged or uneven-aged fir stands.

A few fixed tables of optimum structures already prepared for the mid points of site quality classes, normal stand density and one or two target diameters are not enough to orientate uneven-aged fir forests to the optimum structures (Eraslan-Yüksel-Giray, 1984). For this reason, a new table for each optimum structure that maximizes stand volume increment must be dynamically reproduced with the help of computer according to site quality index, any desirable target diameter and stand density degree.

It is nonsense to separate the existing structures of uneven-aged fir forests into characteristic deviation classes according to the deviation forms that they exhibit (Eraslan, 1982). These deviation classes indicate various degrees of wrong interventions performed to fir stands. The single silvicultural method to be applied in order to orientate the stands in this appearance to the optimum structure is to remove the increments dictated by the diameter increment relationship depending on the relevant optimum structure from the stand. For this purpose, the increments of positive deviations must be removed from the diameter classes surrounding the aggregation center.

The fir yield tables given by Saraçoğlu can not be used in the spoiled uneven-aged fir stands. For this reason, another computer program was written by Gafura who is a forest researcher in the Forest Faculty of Istanbul University, in order to take the spoiled uneven-aged fir stands to the optimum structure. This program provides some tables that show how and when to work within the spoiled uneven-aged fir stands through a long period up to the optimum structure. After obtaining the optimum structure, the fir yield tables given by Saraçoğlu can be used. The length of the regulation period depends on the degree of destruction in the spoiled uneven-aged fir stands.

Fir selection forests in Turkey have an increment potential more than the potential of even-aged forests. As long as target diameter decreases, annual volume increment also increases in uneven-aged fir forest. For example, when the centenary volume increment is 1,851 m^3/ha for 40 cm target diameter, it is 1,745 m^3/ha for 60 cm target diameter (Saraçoğlu, 1988). These amounts are much more than the centenary volume increment 1,041 m^3/ha in oriental spruce stands in the northeast of Turkey which produce the biggest increment. If it is wanted to produce mass wood, target diameter must be decreased in uneven-aged fir stands.

It is very prejudicial to use Hufnagel's diameter class method in the calculation of allowable cut in uneven-aged fir forests because it is not based on the diameter increment relationship. The means of transition times is not meaningful since transition times do not present the normal distribution. It is not also possible to use a nonsence value in the allowable cut formula. So, Hufnagel's diameter class method that calculating the allowable cut using mean trees must be no longer used and increment computations must be made depending on single tree growths.

The optimum diameter distributions (optimum structures) must be a structure dynamically computed for each site quality index and target diameter as to maximize the volume increment, not as a few stable structures representing site quality classes and one or two target diameters.

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