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How stem defects affect the capability of optimum bucking method?

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Abstract: In forest harvesting activities, computer-assisted optimum bucking method increases the economic value of harvested trees. The bucking decision highly depends on the log quality grades which mainly vary with the surface characteristics such as stem defects and form of the stems. In this study, the effects of stem defects on optimum bucking method was investigated by comparing bucking applications which were conducted during the logging operations in two different Brutian Pine (*Pinus brutia* Ten) stands. In the applications, the first stand contained the stems with relatively more stem defects than that of the stems in the second stand. The average number of defects per log for sample trees in the first and the second stand was recorded as 3.64 and 2.70, respectively. The results indicated that optimum bucking method increased the average economic value of harvested trees by 15.45% and 8.26 % in the stands, respectively. Therefore, the computer-assisted optimum bucking method potentially provides better results than that of traditional bucking method especially for the harvested trees with more stem defects.

Anahtar kelimeler: Tree surface properties, log quality grades, cross-cutting, Brutian pine

Gövde kusurları optimum boylama metodunun başarısını nasıl etkiler?

Özet: Orman ürünlerinin üretiminde kullanılan bilgisayar destekli optimum boylama metodu üretilen ağaçların ekonomik değerini arttırmaktadır. Boylama kararı, gövde kusurları ve gövde formu gibi yüzey karakteristiklerine göre değişen tomruk kalite sınıflarına bağlıdır. Bu çalışmada, gövde kusurlarının optimum boylama metodu üzerindeki etkisini incelemek için iki farklı Kızılçam (*Pinus brutia* Ten) meçceresinde üretim çalışmaları sırasında yürütülen boylama uygulamaları karşılaştırılmıştır. Uygulamalarda, birinci meçceredeki gövdeler ikinci meşceredekilere oranla daha fazla gövde kusuru içermektedir. Birinci ve ikinci meşcerelerde, örnek ağaçlarda her bir tomruk için ortalama kusur sayısı sırasıyla 3,64 ve 2,70 olarak kaydedilmiştir. Sonuçlar optimum boylama metodunun bu meşcerelerde üretilen ağaçların ortalama ekonomik değerini sırasıyla %15,45 ve %8,26 oranında arttırdığını göstermiştir. Buna göre, bilgisayar destekli optimum boylama metodu fazla sayıda gövde kusuru içeren ağaçlarda potansiyel olarak geleneksel boylama yöntemine göre daha iyi sonuçlar sağlamaktadır.

Keywords: Ağaç yüzeyi özellikleri, tomruk kalite sınıfları, seksiyonlara ayırma, kızılçam

1. INTRODUCTION

The socio-economic changes due to population growth, industrialization, and economic development have increased the public pressure on forest resources, especially on wood based products (Bishop, 1998). Besides, the economic value of wood based products represents the highest proportion in total economic value of forest resources in Turkey. The wood based products include logs, poles, industrial wood, pulp wood, fiber-particle wood, and sapling wood.

The logs are the most important wood based product in terms of production quantity and economic value in forest industry. Approximately 83.17% of the log production was obtained from coniferous trees (GDF, 2009). Brutian Pines (*Pinus brutia* Ten) are the major source of logs among all the coniferous trees in

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Turkey. The woods of Brutian pines are used in producing lumber, construction materials, telephone and mine poles, pulp and paper, and composite materials (Güler, 2007).

The logs are produced by bucking the trees into short lengths considering the log quality grade, log size (diameter and length), and unit sale prices (Akay et al., 2010). In Turkey, the traditional bucking method has been applied based on the loggers' work experiences. Bucking the trees in a way that maximizes the total economic value of harvested the trees is called optimum bucking method (Sessions, 1988). Optimization methods such as network analysis, linear programming, and dynamic programming have been used to implement computer-assisted optimum bucking methods (Sessions et al. 1989; Laroze and Greber, 1997).

The log grade, size, and unit price should be accurately evaluated and entered into the optimum bucking method (Akay, 2009). The log grades vary depending on the log sizes and surface characteristics such as stem defects and form of the stems. Especially, the stem defects such as existence of knots, wounds, rots, cracks, bending, and sweep on the logs can significantly affect the bucking decision (Olsen et al., 1997). The Figure / Şekil 1 indicates the sample views of common stem defects.

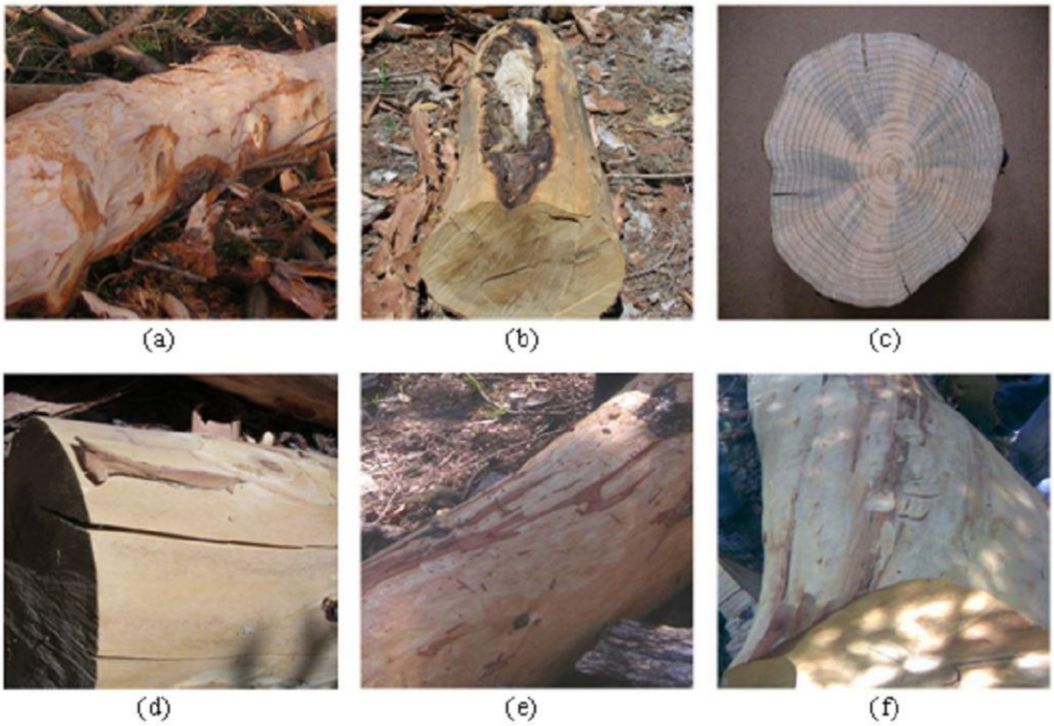

Figure 1. The stem defects: a) knots b) wounds c) rots d) cracks e) bending f) sweep
Şekil 1. Gövde kusurları: a) budaklar b) yaralar c) çürükler d) çatlaklar e) eğilme f) kıvrıklık

According to the grading rules practiced in Turkey, the saw logs are divided into three main quality grades including the first, second, and third grades. The log grade is mainly determined by the number, size, location, and type of the stem defects. Besides, tree ring widths, warm holes, difference between end diameters, gutters, twin piths, and eccentric growth. Table / Tablo 1 indicates the grading rules for the commercial coniferous trees in Turkey (Bozkurt and Goker, 1981).

The size and frequency of the knots is one of the most important factors in determining the bucking points (Barszcz, 1989). The remaining parts of living and dead branches in the wood are called knots (Susnjar et al., 2006). Natural pruning, due to a lack of sunshine, results in dead knots in the lower parts of the stem, while sound knots are generally located in the upper parts (Uusitalo and Isotalo, 2005). The existence of knots on the stem also increases the processing time of bucking operation (Rebula, 1987). The deterioration agents such as insects, stain fungi, and decay fungi cause rot formations which result in serious reductions in wood quality (Lowell et al., 1992; Akay et al., 2006; Akay and Tutus, 2006). The dimensions of the wounds (i.e. diameter, length, width, and depth) also influence the bucking decisions.

Table 1. Log quality grading rules for coniferous trees in Turkey (Bozkurt and Goker, 1981)
Tablo 1. Türkiye'de iğne yapraklı ağaçlar için tomruk kalite sınıfı kriterleri (Bozkurt and Goker, 1981)

Defects	**I. Grade**	**II. Grade**	**III. Grade**
Rot	< 3 cm	< 5 cm	< 7 cm
Rot / Diameter	< %10	< % 25	< % 50
Tree ring widths	< 4 mm	-	-
Diameters of sound knots	< 5 cm	< 8 cm	-
Diameters of dead knots	< 3 cm	< 4 cm	-
Total diameters of sound knots	< 12 cm	< 30 cm	< 60 cm
Total diameters of dead knots	< 4 cm	< 10 cm	< 20 cm
Total diameters of all knots	< 10 cm	< 25 cm	< 40 cm
Bending on one side	< % 2	< % 4	-
Cracks due to lightning or frost	NA	< % 25	-
Depth of surface cracks / Diameter	< 3 cm	< 1/5	-
Width of surface cracks / Diameter	NA	< 1/20	-
Diameter / Length of heartwood and sapwood cracks	< 1/2	< 1	< 2
Diameter / Depth of heartwood and sapwood cracks	< 1	< 1	< 1
Sweep	< 10 cm	< 20 cm	< 30 cm
Depth of worm holes / Diameter	< 1/15	< 1/10	-
Difference between end diameters	< 2 cm	-	-
Depth of gutters / Diameter	< 1/10	< 1/5	-
Twin piths	NA	Exist	Exist
Eccentric Growth / Diameter	< 1/20	< 1/10	-
Wound diameter / Diameter	< 1/20	< 1/10	-
Wound length	< 0.50 m	< 0.75 m	< 1.0 m
Wound width / Diameter	< 1/10	< 1/5	< 1/3
Wound depth / Diameter	-	< 1/4	< 1/5

The inappropriate felling operations or lightning may result in serious cracks along the stems. The dimensions (i.e. width, depth, diameter) and location of these cracks (i.e. surface, heartwood, sapwood) are effective factors in bucking the logs into quality grades. The bending and sweep are other common stem defects that influence the log grade in coniferous trees, especially in pines. If bending and twisting are not located on a single log, there can be 4, 6, and 8 defects on the first, second, and third grade logs, respectively (Bozkurt and Goker, 1981).

In this study, the influence of stem defects on optimum bucking method was investigated by comparing two bucking applications taken place during the logging operations in two different Brutian Pine (*Pinus brutia* Ten) stands. The first stand, located in Forest Enterprise Chief (FEC) of Mudanya in the western city of Bursa, contained the stems with relatively more defects, comparing with the second stand in FEC of Saimbeyli in the Mediterranean city of Adana in Turkey. The capability of optimum bucking method was compared with traditional bucking method within each stand. Then, the potential economic gain of harvested trees by using optimum bucking method was compared between the stand.

2. MATERIAL AND METHODS

2.1 Optimum Bucking Method

In this study, dynamic programming based optimum bucking method with a node-labeling technique was implemented to systematically search for the optimum bucking solution with maximum tree value (Sessions et al., 1988a; Akay et al., 2010). In this method, trees are represented by network system where bucking points and possible log lengths are represented by "node" and "arc", respectively (Figure / Şekil 2). The value of each “arc” is economic value of the log, which can be computed by multiplying the log volume with the average unit price.

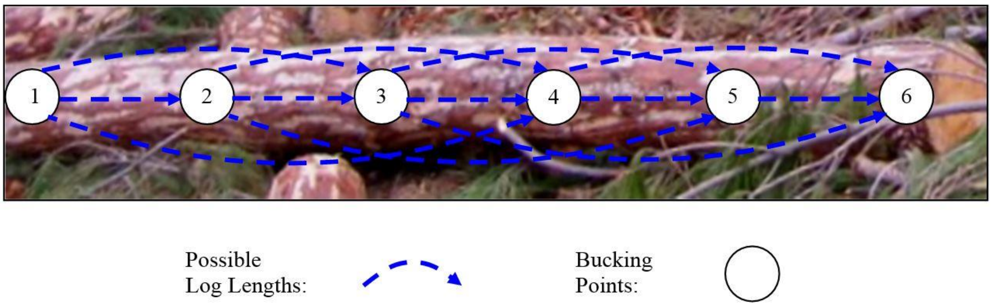

Figure 2. Network system of a sample tree in optimum bucking algorithm
Şekil 2. Optimum boylama algoritmasında örnek bir ağacın network sistemi

To ensure the capability of optimum bucking method, log size, log grade, and unit price should be accurately introduced into the algorithm (Sessions et al., 1988b). The log grades are determined based on the grading rules for the commercial coniferous trees in Turkey (Bozkurt and Goker, 1981). The current market prices for logs of various sizes and grades are required to run optimum bucking algorithm. If there is a transition from one grade to another grade along a log, the grade at small diameter of the log is considered for entire log.

The optimum bucking algorithm is subject to various limitations such as minimum log diameter at the mid point of a log and minimum and maximum log lengths. The minimum log length and diameter are generally considered as 2 m and 19 cm, respectively. The maximum acceptable log length, however, varies depending on the logging methods, forest road standards, and capabilities of transportation equipment.

2.2 Bucking Applications

The optimum bucking applications were performed during the harvesting operations in Brutian Pines stands located in Forest Enterprise Directorates (FEDs) of Bursa and Saimbeyli in Forest Regional Directorates (FRDs) of Bursa and Adana, respectively. The study areas were located in Forest Enterprise Chiefs (FECs) of Mudanya and Saimbeyli in the FEDs of Bursa and Saimbeyli, respectively.

Optimum bucking method was applied on randomly selected 30 sample trees to approximate a normal distribution in each study area. The size (i.e. length, diameter) and grade information for the logs of each sample tree was recorded just after bucking the trees by using traditional bucking method. In both study areas, the maximum log length was 4 m. The extracted logs were transported to the landing areas by using ground based skidding techniques. The average log price for each log grade was determined based on the most recent auctions taken place in the local FEDs. The logging and transportation costs were not taken into account.

In the field studies, general stand information such as tree height and tree diameter at breast height were measured for each sample tree by using chain tape and compass, respectively. GPS and clinometers were utilized to measure UTM coordinates, ground elevation, and ground slope data at the stump locations of sample trees. Besides, the stem defects (i.e. knots, wounds, rots, cracks, bending, and sweep) on each log of sample trees was observed in the field. Then, the number of stem defects on each sample tree was recorded under three types; 1) knots, 2) wounds, rots, and cracks, 3) bending and sweep.

3. RESULTS AND DISCUSSION

The results indicated that, bucking patterns generated by optimum bucking method was different from the bucking patterns generated by the traditional bucking method for all of the sample trees in both stands. The previous studies indicated that the traditional bucking method may reach the same bucking pattern of optimum bucking method if the trees form straight stems with only few defects (Wang et al., 2004). The

FECs of Mudanya and Saimbeyli in Turkey and locations of sample trees based on their UTM coordinates were indicated in Figure / Şekil 3 generated by ArcGIS 9.3 software.

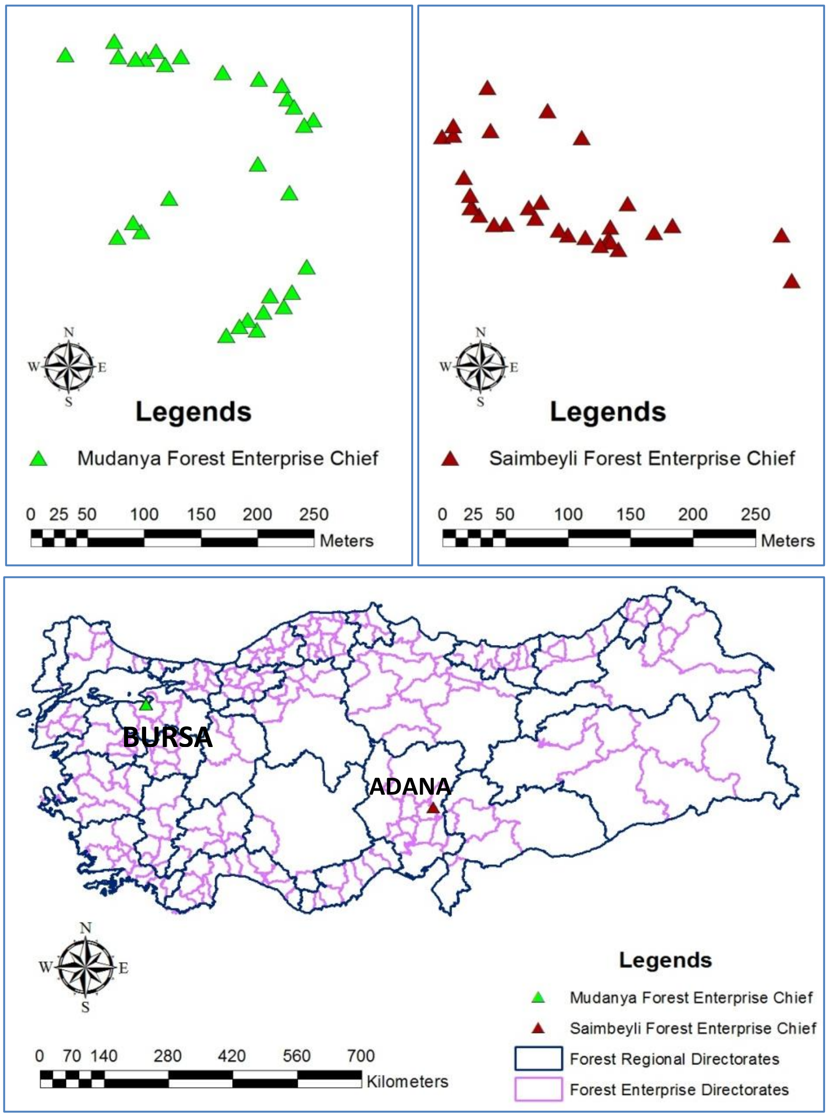

Figure 3. The locations of the study areas
Şekil 3. Çalışma alanı lokasyonu

The general information about the first stand located in FEC of Mudanya and the second stand located in FEC of Saimbeyli were listed in Table / Tablo 2. The average tree diameter at breast height in both stands was similar while the average tree height in the second stand was greater than the average height in the first stand. The average number of stem defects on each sample tree was listed for both stands in Table / Tablo 3. The results indicated that the average number of defects per log for sample trees in the first and the second stands was 3.64 and 2.7, respectively.

In the first stand, the average number of stem defects per tree was 15.77, 2.47, and 1.41 for the defect types of I (i.e. knots), II (i.e. wounds, rots, and cracks), and III (i.e. bending and sweep), respectively. In the second stand, the average number of stem defects per tree for three defect types was 12.4, 1.97, and 1.32, respectively. This verified that the major source of stem defects is existence of knots while other defect types are not significant (Barszcz, 1989). To investigate whether there is a difference between optimum bucking method and traditional bucking method in terms of economic values of the harvested trees, one-way ANOVA analysis was implemented by using SPSS 15.0 statistical software.

Table 2. The general information about the study areas
Tablo 2. Çalışma alanı genel bilgileri

Sample Stands	Ground Slope (%)	Elevation (m)	Diameter (cm)	Height (m)
Stand I	25.00	259.00	34.40	12.57
Stand II	61.40	912.97	35.37	16.87

Table 3. The average number of stem defects on each sample tree for both stands
Tablo 3. Her iki meşcerede örnek ağaçlara ait ortalama gövde kusuru sayısı

Tree No	Defect Types in Stand I			Defect Types in Stand II		
	I	II	III	I	II	III
1	13	1	1	6	1	-
2	15	3	-	4	-	-
3	18	2	2	10	2	1
4	9	1	-	11	2	
5	11	2	1	18	3	1
6	8	2	-	6	-	-
7	6	1	-	3	1	-
8	12	2	1	7	1	1
9	14	3	1	10	2	
10	13	2	-	11	2	1
11	19	3	2	8	1	-
12	14	2	1	6	1	1
13	16	3	1	12	2	2
14	22	4	2	19	3	1
15	11	2	1	7	1	-
16	18	3	2	17	1	2
17	23	4	2	8	2	1
18	21	2	2	14	2	2
19	16	3	1	16	3	1
20	25	4	2	17	4	1
21	20	3	-	18	2	2
22	12	2	1	11	2	1
23	24	3	2	18	3	-
24	21	4	1	20	3	2
25	17	2	1	19	2	1
26	11	2	-	11	1	-
27	16	3	2	13	2	2
28	19	3	1	17	1	-
29	14	1	1	20	3	1
30	15	2	-	15	2	1

The results indicated that the difference for values of sample trees between bucking methods was not significant in both stands (*p=0.233* and *p=0.454*). However, the average economic value of sample trees produced by optimum bucking method and traditional bucking method was 51.02 Euro and 44.58 Euro, respectively, in the first stand. In the second stand, the average economic value of sample trees was 62.87 Euro and 58.53 Euro due to using optimum bucking method and traditional bucking method, respectively. Therefore, the optimum bucking method increased the potential average value of the sample trees by 15.45% and 8.26% in the first and the second stands, respectively. In a similar study, Serin et al. (2009) reported that the average economic gain of using optimum bucking method was about 11.10% for a sample Brutian Pine stand in the Mediterranean region of Turkey.

The capability of optimum bucking method increased in a case of the first stand where harvested trees contain greater number of stem defects, which made the loggers' jobs even more difficult in applying traditional bucking method (Akay, 2009). To investigate the effect of stem defects on optimum bucking method within the first stand, the sample trees were regrouped into 4 groups based on the number of defects; 1) ≤ 10 defects, 2) >10 and ≤ 15 defects, 3) >15 and ≤ 20 defects, 4) >20 defects. It was found that 38% of the sample trees were in Group IV, while 27%, 22% and 13% of the trees fell into Group III, II, and I, respectively (Figure / Şekil 4). Then, the average economic gain of using optimum bucking method was computed for sample trees of defect groups. Table 4 illustrates the average number of defects and average economic gain of using optimum bucking method for each group of stem defects. The results indicated that the average value gain of using optimum bucking method increased as the average number of stem defects increased.

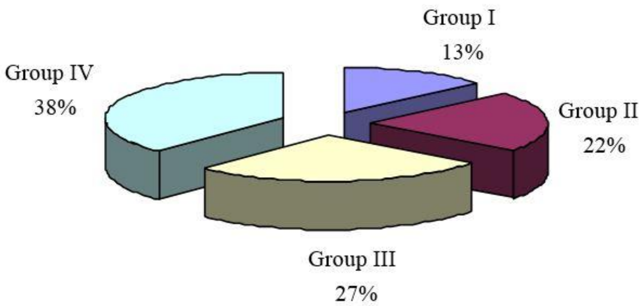

Figure 4. The distribution of the sample trees according to defect groups in the first stand
Şekil 4. Birinci meşcerede örnek ağaçların kusur gruplarına göre dağılımı

Table 4. The groups of stem defects and associated economic gains in the first stand
Tablo 4. Birinci meşcerede gövde kusuru grupları ve ekonomik kazançları

Defect Groups	Average Number of Stem Defects	Average Economic Value Gain (%)
Group I	9.00	12.70
Group II	14.43	13.15
Group III	18.25	14.73
Group IV	25.33	17.96

4. CONCLUSIONS

The stem defects make the bucking decision a complex problem which can not be solved easily by using traditional bucking method. In this study, the optimum bucking applications were evaluated during the logging operations of two Brutian Pine stands to investigate the influence of stem defects on the capability of optimum bucking method. The average number of total stem defects per tree was 19.27 and 15.07 in the first and the second stands, respectively. The major source of stem defects was existence of knots along the stems in both stands. The average economic value gain of harvested trees due to using optimum bucking method was greater in the first stand (15.45%) than that of the second stand (8.26 %). The effect of stem defects on optimum bucking method was also analyzed within the first stand. Overall results from this study indicated that the optimum bucking method provided better results for the harvested trees with more stem defects.

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