Eur J Forest Eng 2017, 3(2): 61-65

Potential Contribution of Optimum Bucking Method to Forest Products Industry*

Abdullah Emin Akay**

Bursa Technical University, Faculty of Forestry, 16310 Yıldırım, Bursa, Turkey.

Abstract

In production of forest products, it is important to produce high quality timber with maximum economic value while considering current market demands. After felling, trees are limbed, barked, and bucked. Bucking stage is critical to increase economic gain in timber production. The process of dividing a tree into sections with respect to required quality classes is called bucking. Optimum bucking is cross-cutting of a tree into the sections that maximize the total economic value. Previous studies indicated that optimum method potentially increases economic value of the forest product up to 10% or more. On the other hand, optimum bucking requires large number of bucking combinations that can be quickly generated by computer-assisted methods. Some of these methods may include network analysis, dynamic programming, and heuristic techniques. In Turkey, bucking is generally performed based on loggers' experiences without using any scientific approach. In this study, dynamic programming based optimum bucking method was implemented to maximize economic value in tree bucking. The bucking application was evaluated in a selective cutting of Yellow Pine (*Pinus sylvestris*) trees in the city of Bolu. The optimum bucking approach was compared with traditional bucking method, and the approximate contribution of using optimum bucking approach was computed. The results indicated that using optimum bucking method increased the total value of harvested trees by 8.7%. It was also revealed that performance of optimum bucking method is mainly influenced by log lengths and diameters.

Keywords: Tree bucking, optimum bucking, dynamic programming, *Pinus sylvestris*

1. Introduction

The primary income sources of the forest industries are wood based products (e.g. logs, wire poles, mine poles, industrial wood, pulp wood, and fire wood) in Turkey. Due to population growth, industrialization and economic development, the forest resources have been under great pressure. Therefore, they should be produced by using appropriate methods in order to ensure sustainable management of forest resources (Akay, 2009).

In Turkish forest industry, the logs are considered as one of the most important product types in terms of both quantity and economic value (Yenilmez, 2010). In common practice, logs are produced by felling, delimbing, bucking, and debarking the trees. To increase productivity of log production, especially bucking of the trees should be performed in an optimum way that maximizes the total value of the trees.

In traditional bucking method, the trees are cut by depending on the loggers' experiences which may not guarantee the optimum bucking solution; however, optimum bucking method employing computer-assisted techniques can search for the optimum solution among a large number of alternatives. Such a problem with large solution space can be solved using modern optimization methods that systematically search for the best solution. These methods may include network analysis, linear programming (LP), dynamic programming (DP), and heuristic techniques (Laroze and Greber, 1997). The previous studies indicated that optimum bucking method can increase the economic value of timber more than 10% (Wang et al., 2007). Thus, implementing optimum bucking method has great potential to increase the total economic value of log production in Turkish forest industry.

Akay (2009) studied the effects of forest harvesting techniques on optimum bucking method during a logging operation in Oriental Spruces stand in the city of Giresun in northeastern Turkey. Two harvesting

[*]This work has been partially presented in IFES2017 Symposium

[**]Corresponding author: Tel: +90-224-3003426 E-mail: abdullah.akay@btu.edu.tr

Received 10 December 2017; Accepted 22 December 2017

techniques (i.e. manual skidding and mechanized skidding) were evaluated by considering the maximum allowable log lengths. The results indicated that optimum bucking method increased the economic value of the harvested trees by approximately 11% during mechanized skidding method with increased maximum allowable log length.

The effects of optimum bucking method on the total economic value of timber were investigated by Serin et al. (2010). They evaluated optimum bucking method during the logging operations of sample Brutian Pine stands. The results indicated that the economic value of the harvested trees was increased by 4.7% using optimum bucking method. Akay et al. (2010) developed a stem-level optimum bucking algorithm and the capabilities of the model were tested during a selective cutting of Taurus Fir stands in Kahramanmaras in eastern Mediterranean region of Turkey. The results indicated that optimum bucking method increased the value of the harvested trees by 9.31%.

Akay et al. (2015) investigated the effects of stem defects on optimum bucking method during the logging operations in two different Brutian Pine stands. In the first stand, stems had relatively more defects than the second stand had. The results indicated that the optimum bucking method provides better results for the harvested trees with more stem defects. Pak and Gülci (2017) evaluated economic gain of using optimum bucking method in Oriental Beech stand located in northeastern region of Turkey. Network 2000 program was used to run optimum bucking method in a sample application. The results indicated that optimum bucking method increased the average economic value of harvested deciduous trees by 14.37%.

In this study, stem-level optimum bucking approach was implemented by using dynamic programming method. The application was conducted in a harvesting unit of Yellow Pine stand located in the city of Bolu in Turkey. The results from optimum bucking method were compared with the results achieved by using the traditional bucking method.

2. Material and Methods

2.1. Study Area

The study was implemented in Yellow Pine stands located in Çaydurt Forest Enterprise Chief of Aladağ Forest Enterprise Directorate in Bolu Forest Regional Directorate (Figure 1). The average elevation and ground slope were 1611 m and 26%, respectively. The trees were cut and bucked by using chainsaw, and skidded to the landing by farm tractors. Optimum bucking method was applied on randomly selected 30 sample trees in the field and then optimum bucking data including log diameter, log length, and log grade were recorded for each log of sample trees. The average tree height and tree diameter at breast height were measured as about 26 m and 40 cm, respectively.

2.2. Optimum Bucking

In this study, dynamic programming method was used to develop stem-level optimum bucking algorithm (Sessions *et* al., 1988). In this algorithm, cross-cutting location was considered as "node" and log length was "arc" between nodes (Figure 2). The log value was computed based on the log volume and unit log price.

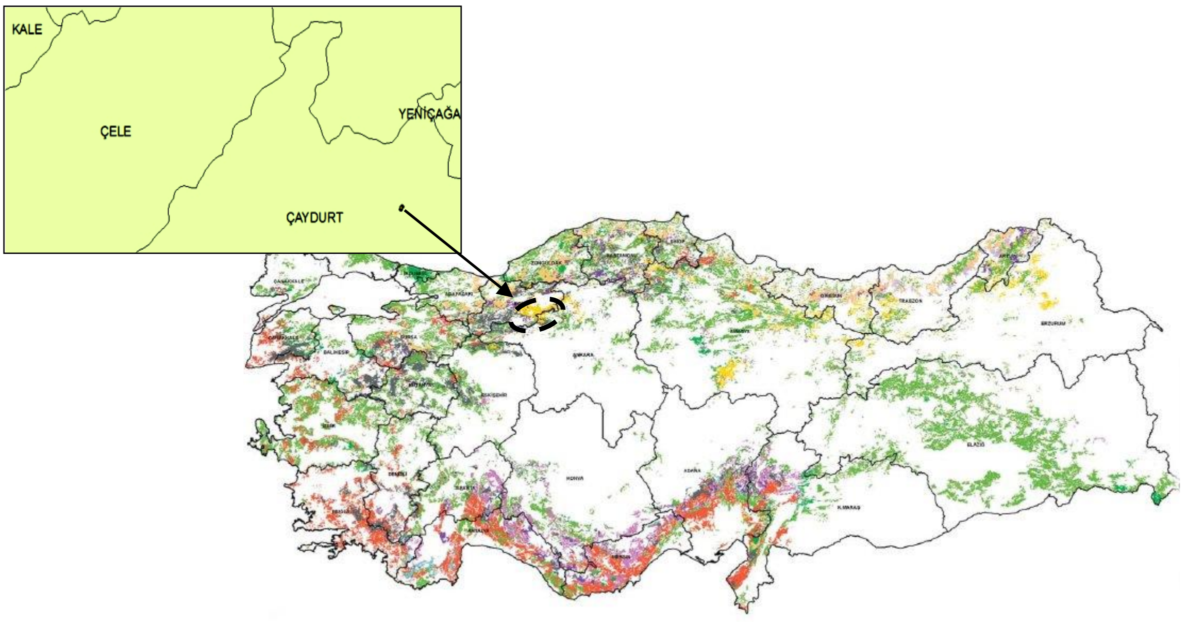

Figure 1. Study area

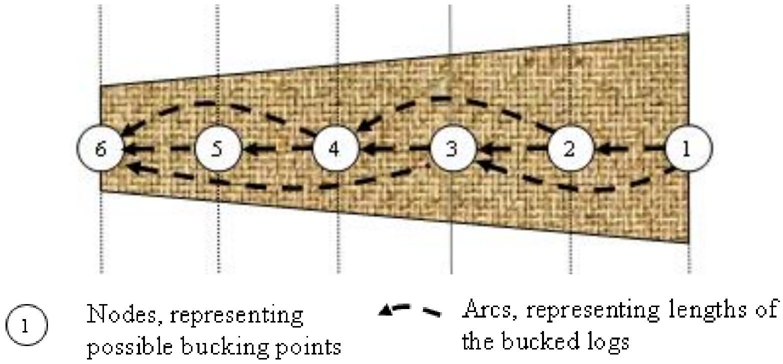

Figure 2. Network representation of a sample tree

The log volume was computed as function of log length and diameter at the midpoint of the log, while the unit log price was obtained from the most recent local auctions:

$$V_i = \frac{\pi}{40000} d_i^{\,2} L_i \qquad (1)$$

d_i = diameter at the midpoint (cm)
L_i = log length (m)

Then, optimum bucking algorithm was used to determine the optimum "path" of arcs that provides maximum economic value from the whole tree. In order to implement optimum bucking method, log sizes (i.e. diameter and length classes) and log grades were entered into the algorithm. The length and diameter classes used for coniferous trees in Turkey were indicated in Table 1 (Kalıpsız, 1999). In determining the log grade, surface characteristics of the logs such as shape, knot size and density, and cracks, bending, and twisting were observed in the field (Olsen *et al.* 1997). Besides, current information about the market prices were also obtained for each log grade with various length and diameter classes.

Table 1: The length and diameter classes for the logs of coniferous trees

Length Classes	Length (m)	Diameter Classes	Middle Diameter (cm)
Short	1.5-2.5	Small	19-29
Normal	3.0-5.0	Medium	30-39
Long	5.5-8.0	Large	40-49
Very Long	≥ 8.5	Very Large	≥ 50

In the algorithm, there are *n* nodes and *n-1* bucking decisions. The network consists of exactly *N* comparisons where *N* equals the number of possible logs. The optimal cutting algorithm has following six mail steps (Akay et al., 2010):

1. Label all possible bucking cuts from the base to the top of the tree,
2. Define all feasible logs by their beginning and ending nodes (Begnode(i), Endnode(i)) and assign Value(i) to each log based on Begnode(i), Endnode(i).
3. Sort the N logs by their beginning node
4. Initialize Bestvalue(i), the highest value at each node i = 0
5. For i = 1 to N
   If Bestvalue (Begnode(i)) + Value(i) > Bestvalue(Endnode(i)) Then
   Bestvalue(Endnode(i) = Bestvalue(Begnode(i))+Value(i)
   Prednode(Endnode(i)) = Begnode(i)
   End If
   Next i
6. Use predecessor nodes from node n to node 1 to identify the optimal log mix

In statistical analysis, SPSS® statistic software was used to investigate whether there is a significant difference for values of the set of harvested trees between traditional bucking method and optimum bucking method. The breast height diameters were regrouped into three classes (small < 40 cm; medium = 40-50 cm; and large > 50 cm) to investigate the effects of different diameter classes on value gain of bucked logs due to using optimum bucking methods. The average lengths of bucked logs for harvested trees were also regrouped into three classes (short < 3.0 m; medium = 3.0-3.5 m; and long > 3.5 m) to investigate whether value gain of bucked logs were significantly affected by different log classes.

3. Results and Discussion

Bucking patterns generated by optimum bucking method was different from the bucking patterns generated by the traditional bucking method. Table 2 indicates average log length, economic value and gain for each sample tree. The average log lengths were 3.47 m and 3.42 m for the optimum bucking and traditional bucking methods, respectively. When comparing economic value of individual trees, optimum bucking method increased the economic value of average tree value by 9.44%.

Table 2. The average log length and economic value of trees for both bucking methods

Trees	Average Tree Length (m)		Economic Value of Trees (Turkish Lira)		Value
	Traditional Method	Optimum Bucking	Traditional Method	Optimum Bucking	Gain (%)
1	3.60	3.00	243.42	246.98	1.46
2	2.75	3.67	82.95	95.78	15.47
3	3.80	3.80	273.13	307.1	12.44
4	4.00	3.20	166.52	175.1	5.15
5	2.83	3.40	243.02	291.04	19.76
6	3.75	3.75	254.64	278.79	9.48
7	3.20	3.20	195.72	211.62	8.12
8	3.00	4.00	93.58	104.2	11.35
9	3.00	4.00	102.85	121.18	17.82
10	3.25	3.25	144.82	162.98	12.54
11	3.20	3.20	201.35	240.95	19.67
12	3.40	3.40	291.67	331.14	13.53
13	3.00	3.75	149.39	167.68	12.24
14	3.60	3.60	292.20	323.39	10.68
15	3.80	3.80	283.32	291.45	2.87
16	3.80	3.80	273.49	274.99	0.55
17	3.75	3.75	245.64	268.5	9.31
18	3.50	3.50	389.63	399.57	2.55
19	3.17	3.80	287.92	311.89	8.33
20	3.60	3.00	248.53	258.69	4.09
21	3.17	3.17	269.40	303.41	12.62
22	3.60	3.00	239.30	260.62	8.91
23	3.00	3.00	115.05	126.5	9.96
24	3.80	3.17	308.12	334.7	8.63
5	3.17	3.17	250.12	270.06	7.97
26	3.60	3.60	228.34	229.2	0.38
27	3.60	3.60	267.75	288.88	7.89
28	3.50	3.50	130.38	146.38	12.27
29	3.67	3.67	350.03	370.22	5.77
30	3.40	3.40	201.42	224.1	11.26

The statistical results indicated that the difference for values of bucked trees between traditional bucking and optimum bucking methods was not significant (*p = 0.329*). However, using optimum bucking method increased the total value of the harvested trees by 8.7%, comparing with the traditional bucking method. In a similar study where capabilities of optimum bucking were tested during a selective cutting of Taurus Fir, optimum bucking method increased the value of the harvested trees by about 9% (Akay et al, 2010).

The effects of log diameter on value gain of optimum bucking method were tested considering three diameter classes (small, medium, and large). Table 3 indicates the value gain for each diameter class. It was found that medium diameter class provided the highest average value gain of 9.77%. Pak and Gülci (2017) also stated that the highest value gain of optimum bucking method was received in medium diameter class.

Table 3. The value gains of optimum bucking for three diameter classes

	Diameter Classes	Number	Average	Minimum	Maximum
Tree Value (%)	Small	12	8.93	0.38	17.82
	Medium	18	9.77	2.55	19.76
	Large	--	--	--	--

The effects of log length on value gain of optimum bucking method were also tested considering three length classes (short, medium, and long). The value gain for each length class was shown in Table 4. The results indicated that long class provided the highest average value gain of 14.59%. In a similar study, Akay (2009) reported that increasing the maximum log length from 4 m to 5 m increased the potential value gain of optimum bucking method from 8.55% to 11.26%.

Table 4. The value gains of optimum bucking for three length classes

	Length Classes	Number	Average	Minimum	Maximum
Tree Value (%)	Short	--	--	--	--
	Medium	28	9.07	0.38	19.76
	Long	2	14.59	11.35	17.82

4. Conclusions

Dynamic programming based optimum bucking method was implemented to assess the potential economic value gain in tree bucking. Although there was no significant difference for value of bucked trees between traditional and optimum bucking methods, optimum bucking method increased the total log value. The value gain of the harvested trees tends to increase from small diameter trees to large diameter tress. The value gain also increases as the length of the bucked logs increases, thus, optimum bucking method provides better results for large size logs. Performing bucking in an optimum way is an important factor to increase value in timber production in Turkey. Using optimum bucking method will provide the forest engineers with an optimum solution for quickly evaluating large number of bucking combinations. Besides, implementing modern and advanced methods such as optimum bucking in forestry activities will assist decision makers to manage forest resources in more effective and productive ways.

Acknowledgements

This study is funded by The Scientific and Technological Research Council of Turkey (TUBITAK) with the project number 108O125.

References

Akay, A.E.., 2009. The effects of Forest Harvesting Techniques on Optimum Bucking Application of Oriental Spruce (*Picea orientalis*) Stands in Turkey. *Austrian Journal of Forest Science*, 127(1):25-36.

Akay, A.E., Sessions, J., Serin, H., Pak, M., Yenilmez, N., 2010. Applying Optimum Bucking Method in Producing Taurus Fir (Abies cilicica) Logs in Mediterranean Region of Turkey. *Baltic Foresty*, 16(2):273-279.

Akay, A.E., Serin, H., Pak, M., 2015. How stem defects affect the capability of optimum bucking method? *Journal of the Faculty of Forestry Istanbul University*, 65(2):38-45.

Kalıpsız, A., 1999. Dendrometry. Istanbul University, Faculty of Forestry. Publication No: 3194/354. Istanbul. Turkey. 407 p.

Olsen, E., Stringham, B., Pilkerton, S., 1997. Optimal Bucking: Two Trials with Commercial OSU BUCK Software. Oregon State University, College of Forestry, Forest Research Laboratory. Research Contribution 16. 32 p.

Pak, M., Gulci, N., 2017. A comparative economic evaluation of bucking deciduous trees: A Case study of Oriental beech (Fagus orientalis) stands in Northeastern Turkey. *Journal of the Faculty of Forestry Istanbul University*, 67(1): 72-79.

Serin, H., Akay, A.E., Pak, M., 2010. Estimating the Effects of Optimum Bucking on the Economic Value of Brutian Pine (Pinus Brutia) Logs Extracted in Mediterranean Region of Turkey, *African Journal of Agricultural Researc*, 5(9):916-921.

Sessions, J., Layton, R., Guangda, L., 1988. Improving tree bucking decisions: A net-work approach. *The Compiler*, 6(1), 5-9.

Wang, J., Ledoux, C.B., Mcneel, J., 2004. Optimal Tree-Stem Bucking of Northeastern Species of China, *Forest Products Journal*, 54(2):45-52.

Yenilmez, N., 2010. Applying a Single Tree Level Optimum Bucking Method during Cut-to-length Logging. M.Sc. Thesis. KSU, Faculty of Forestry, Kahramanmaras. Turkey. 216 p.