An Index Method For Estimating Of Harvesting Costs

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Abstract

In investment decisions as well as in forest valuation procedures there is a demand for simple methods to predict or control costs.

In this work, a formula for estimating the harvesting costs is proposed based on the prices and the calculation methods of the Bulgarian regulation for forest valuation (*The Regulation*). The formula simply states that harvesting costs are proportional to skidding distance with percentage corrections for numerous other factors. It approximates very precisely the method of the above Regulation and might be used for preliminary valuations. It also gives an idea how to rank the forest stands according to the harvesting costs. Such ranking might be useful for planning and control of forest harvest.

MATERIALS AND METHODS

The *harvesting costs levels* or *indexes* (*Kostenstufen*) are a classification of forests according to the costs their harvest would require. In general, the harvesting costs levels are an instrument to create comparability of statistical data. In cost analyses, the results of forest districts of a similar mean harvesting cost level should be compared if the aim is to know which of them are running well and which are running bad. The harvesting costs level is also a mean for fast prediction of costs of single forest stands. Fast prediction methods are always useful at least to deliver preliminary results.

In Bulgaria, the state-owned forest districts plan their costs using the Official work standard of harvesting [1]. These norms state the time and workers' wages for a number of operations that are accomplished when harvesting timber. Based on the Official work standard of harvesting and also on primary data about production costs of timber, model calculations and previous scientific works, in 1999 a simplified norm was derived that was aimed to be used for appraisal of the value of forest assets [8]. Since then it known as "the prices of the appraisal regulation". It was twice actualized without changing much, for the last time in 2003, and is still valid [7]. "The prices of the appraisal regulation" involve only the factors of the terrain and the forest structure only and ignore technology which is an advantage and an disadvantage in the same time.

The method to calculate harvesting costs of the Regulation is, as it follows:

$$H = \varepsilon C + \rho S$$

herein

H = harvesting costs,

C = cutting costs for average terrain conditions,

ε = difficulty of cutting site,

S = skidding costs for average terrain conditions,

ρ = difficulty of skidding ways.

The definitions of the factors ε and ρ are given in Appendix 1. Their possible values are

$$\varepsilon = 0{,}9 \div 1{,}2$$

$$\rho = 0{,}9 \div 1{,}2$$

Skidding costs include fix costs and kilometer costs that depend on the distance of skidding.

$$S = F + lK$$

Herein

F = fix costs of skidding

K = marginal costs for 1 km of skidding

l = skidding distance in kilometers

Skidding distances of 0 km are very common in the plains of Bulgaria where the trucks are loaded in the cutting area. However, skidding distances of 2 km are also very common in the mountains, at least in the Balkan and in Pirin. Even longer distances are possible, although rope lines are seldom used. We have postulated here that l ranges from 0 to 4, overestimating the upper border of the parameter's range. The average skidding distance is about 1 km. According to the World Bank Report [9], the mean skidding distance is 840 m.

The costs for cutting and skidding depend on assortment structure:

$$C = a_1C_1 + a_2C_2 + a_3C_3 + a_4C_4$$

$$F = a_1F_1 + a_2F_2 + a_3F_3 + a_4F_4$$

$$K = a_1K_1 + a_2K_2 + a_3K_3 + a_4K_4$$

Herein

a_1, a_2, a_3 and a_4 are the percentages of large stem wood, middle stem wood, small stem wood and piled wood in the stand being valuated, $1 = a_1 + a_2 + a_3 + a_4$.

C_1, C_2, C_3, C_4, F_1, F_2, F_3, F_4, K_1, K_2, K_3 and K_4 are the prices given in table 1.

Table 1

Costs after the Regulation

Assortments and costs BGL/m^3	large timber	middle timber	small timber	piled wood
cutting	**C_1**	**C_2**	**C_3**	**C_4**
conifers	4,2	6,7	8,6	7,3
broadleaved	4,5	7,2	9,8	8,1
Fixed costs for skidding	**F_1**	**F_2**	**F_3**	**F_4**
conifers	5,6	7,6	7,6	7,1
broadleaved	6,0	8,4	8,4	7,0
Kilometer costs for skidding	**K_1**	**K_2**	**K_3**	**K_4**
conifers	2,7	4,7	5,2	4,9
broadleaved	4,2	5,7	6,2	5,0

The percents $a_1 + a_2 + a_3 + a_4 = 1$ are referred to as the assortment structure of harvested timber. They can be obtained by direct measurement in the rare case when the costs of harvested timber must be appraised. For stumpage (standing timber), assortment tables are used. However, standing timber has a fifth component - the harvest waste. If the assortment structure $A_1 + A_2 + A_3 + A_4 + A_5 = 1$ is known, the structure of the harvested timber can be recalculated as follows:

$$a_1 = \frac{A_1}{1 - A_5}, \quad \ldots, \quad a_4 = \frac{A_4}{1 - A_5}$$

In Appendix 2, the Assortment tables for pine stands together with the definitions of assortments are given. The pine stands tables cited here are one of the set of tables included in the *Regulation*.

The norms considered here do not treat transportation costs since transportation costs are paid usually by the buyer. They exist, of course, and have their influence on the prices offered by buyers of cut timber. We did not deal with them because in this work we do not deal with timber prices. In the 60-es, 70-es and 80-es they were well known when forestry and forest production mills were under the same ministry. Then, Bayev [3] established the proportion that seams to be still approximately valid:

Table 2

Transportation costs

Cutting costs	Skidding costs	Transportation costs
100	191	125

RESULTS

Out of table 1, following average proportions can be calculated (table 3):

Table 3

Distribution of harvesting costs between the assortments

Large timber	Middle timber	Small timber	Piled wood
1,00	1,47	1,68	1,42

Distribution of harvesting costs between the tree species

Conifers	Broad-leaved
1,00	1,18

Distribution of harvesting costs between the operations

Cutting costs, *C*	Fixed costs for skidding, *F*	Kilometer costs for skidding, *K*
1,00	1,02	0,68

The proportions of table 3 are weighted means. The calculations are given in (Appendix 3). To accomplish them the usual distribution of assortments in timber sale statistic for Bulgaria were used. The results can be commented as follows. As it is well known, small wood is far more difficult to harvest than large one, although that extreme large wood can also cause problems. In general, hardwood is more expensive for harvesting because it is hard and heavy. And finally, according to local experience, skidding to average distances is twice as costly as cutting.

As it is easy to prove, the calculation method of the Regulation is equivalent to following formula:

$$H = \varepsilon(a_1C_1 + a_2C_2 + a_3C_3 + a_4C_4) + \rho(a_1F_1 + ... + a_4F_4) + \rho l(a_1K_1 + ... + a_4K_4)$$

In order to simplify this formula let us postulate that the average proportions hold in each single case. After elementary mathematical transformations this conducts to following formula:

$$H = 4{,}20\,(1 + 0{,}18\,b)(a_1 + 1{,}47a_2 + 1{,}68a_3 + 1{,}42a_4)\,(\varepsilon + 1{,}02\,\rho + 0{,}68\,\rho\, l)$$

Therein 4,2 is the value of C_1 for conifers, and b is the percent of deciduous species in a mixed stand.

A further simplification can be made if we consider that $a_1 = 1 - a_2 - a_3 - a_4$. It is evident, that

$$H = 4{,}20\,(1 + 0{,}18\,b)(1 + 0{,}47a_2 + 0{,}68a_3 + 0{,}42a_4)\,(\varepsilon + 1{,}02\,\rho + 0{,}68\,\rho\, l)$$

Further on, since the amounts $i = 0{,}18b \le 0{,}18$ and $j = 0{,}47a_1 + 0{,}68a_2 + 0{,}42a_3 \le 0{,}68$ are small, it can be concluded that $(1+i)(1+j) \approx 1 + i + j$, since the ij is even smaller than i and j. That conducts to the formula

$$H = 4{,}20\,(1 + 0{,}18\,b + 0{,}47a_2 + 0{,}68a_3 + 0{,}42a_4)\,(\varepsilon + 1{,}02\,\rho + 0{,}68\,\rho\, l)$$

In order to correct all the damage we made to the formula by simplifying it, a regression analysis was made. For all combinations of skidding distance, difficulty factors and for the tree species and assortment structures of the assortment tables of the *Regulation* the harvest costs were calculated and a formula of the above type was fitted. The regression analysis resulted in

$$H = 4{,}644\,(1 + 0{,}12b + 0{,}52a_2 + 0{,}74a_3 + 0{,}48a_4)(\varepsilon + 1{,}04\rho + 0{,}69\rho l)$$

By the substitution $0{,}48(a_2 + a_3 + a_4) = 0{,}48(1 - a_1)$ and neglecting a small amount ($0{,}04a_2$) we obtain

$$H = 6{,}873\,(1 + 0{,}08b - 0{,}32a_1 + 0{,}18a_3)(\varepsilon + 1{,}04\rho + 0{,}69\rho l)$$

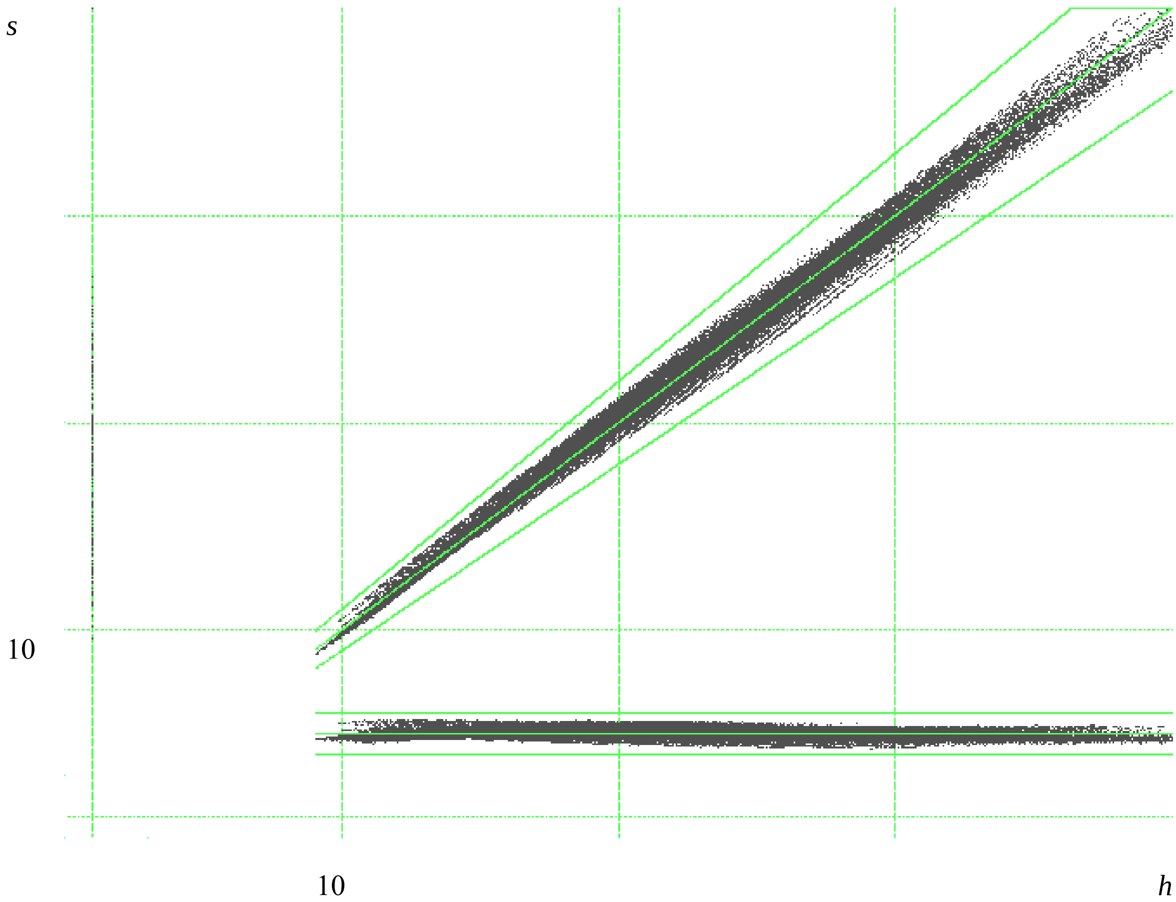
To obtain a more understandable result we wrote 7 × 0,9819 for 6,8733 and obtained finally

$$H = 7\,(1 + 0{,}08b - 0{,}32a_2 + 0{,}18a_3)(\varepsilon + 1{,}04\rho + 0{,}69\rho l)\,0{,}9819$$

This formula was again compared with the assortment tables to be sure that the cosmetic makeup of it was harmless. The result is given on Figure 1. The combinations involved were over 48 000 which made troubles to EXCELL.

Fig. 1

All tree species, comparison of precise and approximate harvest costs values



On the figure, the *x*-axis represents the harvesting costs *h* calculated applying the calculation of the *Regulation* and the *y*-axes represents the results *s* of the simplified formula. The grid lines represent 10 BGL (≈5 EUR). Thus, the range of values reaches from about 10 to 40 BGL. The point cloud close to the diagonal represents the dependence of the simplified formula on the results of the direct application of the Regulation. The straight lines on both sides represent the limits of the 10-percent-error. As it can be seen the error is about than 5%.

The horizontal line gives in another scale the dependence of the relative error *s* / *h* on *h*. The parallel straight lines on both sides represent the 10-percent level of error. As it can be seen, it is by far not achieved.

We do not discuss here standard error (it is 2%) and correlation because the distribution of the data does not represent their frequencies in nature. However, since the maximum error is about 5% in a wide range of values one can conclude that the simplified formula predicts the results of applying the Regulation very exactly.

For single tree species there are bias to be seen. E.g. on fig. 2 and 3 analogous comparisons for spruce and beech are made. Of course, such comparisons were made for all tree species for which there is an assortment table joint to the Regulation – pine, spruce, fir, oak, beach, Q. cerris and poplar. For the conifers, the point cloud is systematically over the diagonal line *y* = *s*, and for the conifers it is systematically under it. Systematic errors might be significantly improved by empirical correction factors. We did not try to develop such factors since even now the error remains about 5%, which is completely sufficient.

Fig. 2

Spruce, comparison of precise and approximate harvest costs values

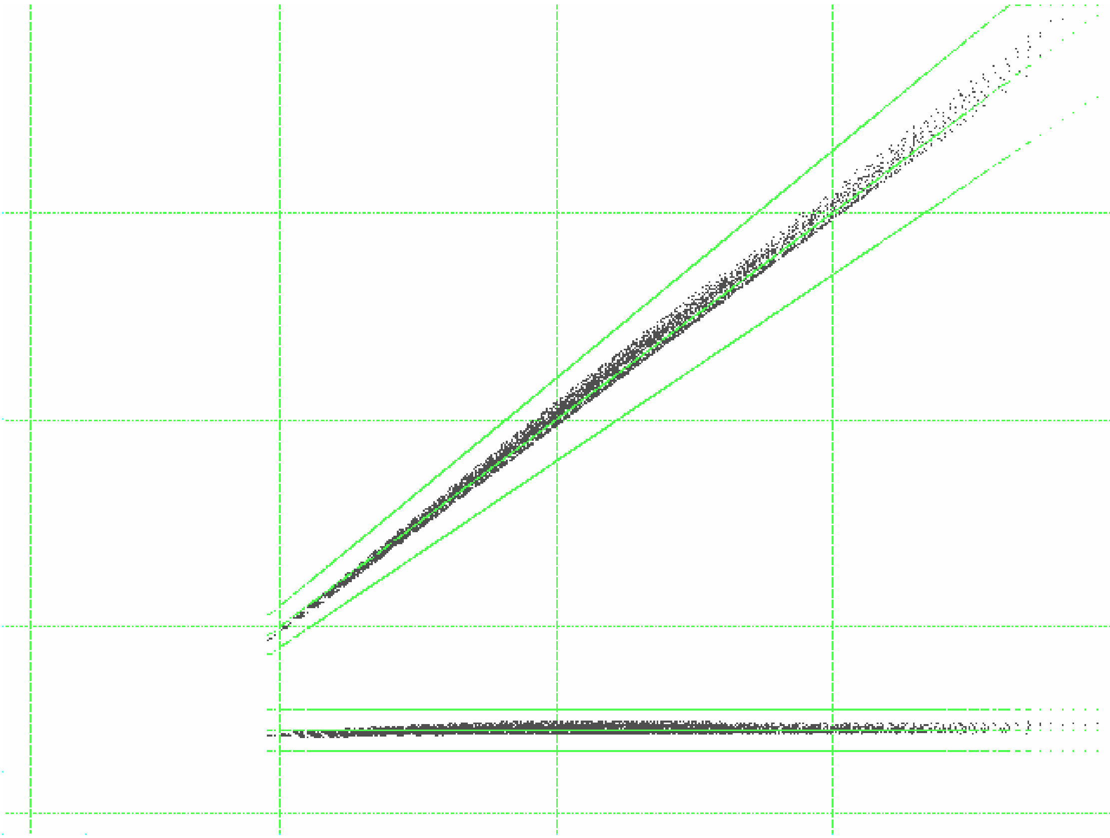
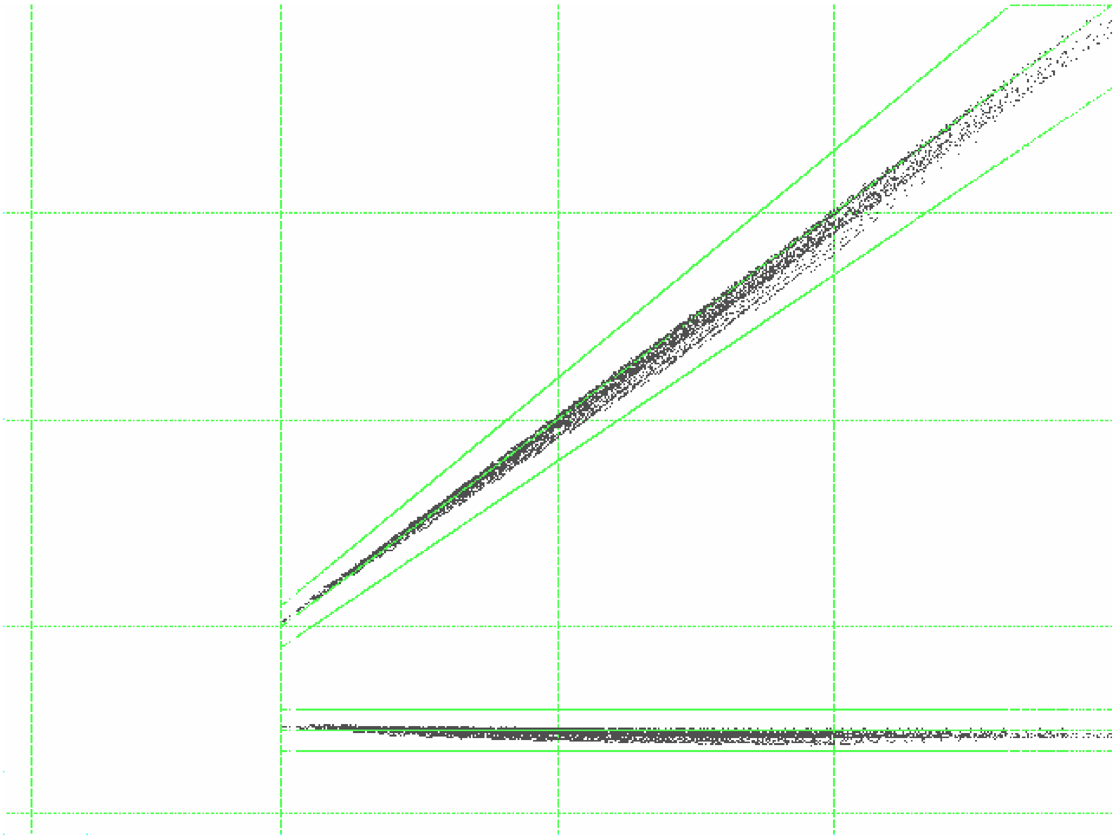


Fig. 2

Beech, comparison of precise and approximate harvest costs values



Finally, we obtain following valuation formula

$$H = 7 \times I$$

where *I* is the harvest cost index, reaching form 1,5 up to 5,5.

$$I = (SI + CI)(1 + P)$$

where *SI* is the skidding index, *CI* is the cutting index and *P* are the correction percents reaching from –32 up to 22 percents.

$$SI = (1{,}04\rho + 0{,}69\rho l) \times 0{,}9819$$

$$CI = \varepsilon \times 0{,}9819$$

$$P = 0{,}08b - 0{,}32a_2 + 0{,}18a_3$$

The parameters *SI*, *CI* and *P* should be better given in tables (Table 4). To use such tables, an appraisal of skidding distance and difficulty of site is needed. This way, the harvest costs estimation is reduced to evident parameters since experts do not make calculations to determine whether conditions are difficult or not and how long the skidding distance is.

It should be noted that table 4[a] reaches up to skidding distances of 4 km and percentages of large timber up to 100. Of course, a 100 % content of large wood is unrealistic for living trees but that shall not make any problem to the table users.

The idea of the present article was to classify the forest stands after the harvesting costs. The domain of values of I suggest to subdivide forests in 4 classes (Table 5). These classes are a proposal for harvesting costs levels or indexes. There are 33-percent differences between the level termed "normal" and the levels termed "easy" and "difficult". That corresponds to the German custom to deal with 3 *Kostenstufen* with 20-percent difference between them. However, due to big skidding distances the variance of costs in Bulgaria is larger.

Table 5

Harvesting costs index

Index	1,5	2	3	4 – 5
Harvesting conditions	Very easy	easy	normal	difficult
Harvesting costs in BGL, H	10	14	21	28

DISCUSSION

The levels of harvesting costs are currently used in German regulations for appraisal of forest assets. The larger problem of typology of economic conditions is treated e.g. by Speidel [10]. The index of harvest costs is related to the so called technical site index ("technischer Standortstyp"). To obtain it, it is sufficient to drop the parameters depending on the forest stand structure. Thus,

$$TSI = SI + 1$$

Since P and CI–1 are quite small amounts, as a rough orientation can be stated that

$$H \approx 7 \times TSI$$

Since both harvest cost level and technical site type are economic parameters they are unstable varying together with prices and technology. A.e. there are many experts who are convinced that the costs for harvesting small wood are underestimated. For example Vassilev [2] found in 1979 following proportions

Table 6

Relative labor consumption of the assortments after Vassilev

	Large wood	middle	small	Non standard logs	Industrial wood	fuel-wood
Conifers	1	1.7	2.9	1.1	2.0	1.7
Broadleaved	1	1.6	2.4	1.1	2.2	1.9

In this result the nonstandard logs, the industrial woos and the fuel-wood are subdivisions of the piled wood.

Which is more, it is sure that harvesting of small wood is going to become more expensive, as it is already in EU countries. Suppose a dramatic change prices that conducts to the proportion

$$C_1 \ : \ C_2 \ : \ C_3 \ : \ C_4 \ = \ 1 \ : \ 2 \ : \ 3 \ : \ 2$$

Well, it conducts to the formula

$$H = 4{,}20\left(1 + 0{,}18b\right)\left(a_1 + 2a_2 + 3a_3 + 2a_4\right)\left(\varepsilon + 1{,}02\,\rho + 0{,}68\,\rho\, l\right)$$

that can be further simplified to

$$H = 8{,}40\left(1 + 0{,}18b\right)\left(1 - 0{,}5a_1 + 0{,}5a_3\right)\left(\varepsilon + 1{,}02\,\rho + 0{,}68\,\rho\, l\right)$$

The proposed formula might hold with a cosmetic change of numeric values because its real base is the postulate that complex price relations can be transformed to straight lines without loosing much. A known non-linear dependence of harvesting costs is that of diameter. Our formula avoids this non-linear dependence being based on the assortment structure that depends on the mean diameter.

CONCLUSIONS

The estimation method proposed can be used for preliminary appraisal of the monetary value of forest assets where time and not accuracy are important.

The method can be also used for orientation in harvesting conditions if standard technology is applied. Of course, we do not propose to the give up precise calculations for planning of costs in the forestry districts and enterprises.

Although a classification based on costs can not be stable in time, the method might be actualized by changing the coefficients and recalculating the tables.

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Table 4a

Skidding Index (SI) for Different Skidding Distances and Site Conditions

Skidding distance *l*, km	Difficulty ρ of skidding ways						
	0,9	0,95	1	1,05	1,1	1,15	1,2
	Skidding index						
0	0,92	0,97	1,02	1,07	1,12	1,17	1,23
0,1	0,98	1,03	1,09	1,14	1,2	1,25	1,31
0,2	1,04	1,1	1,16	1,21	1,27	1,33	1,39
0,3	1,1	1,16	1,22	1,29	1,35	1,41	1,47
0,4	1,16	1,23	1,29	1,36	1,42	1,49	1,55
0,5	1,22	1,29	1,36	1,43	1,5	1,56	1,63
0,6	1,28	1,36	1,43	1,5	1,57	1,64	1,71
0,7	1,35	1,42	1,5	1,57	1,64	1,72	1,79
0,8	1,41	1,49	1,56	1,64	1,72	1,8	1,88
0,9	1,47	1,55	1,63	1,71	1,79	1,88	1,96
1	1,53	1,61	1,7	1,78	1,87	1,95	2,04
1,1	1,59	1,68	1,77	1,85	1,94	2,03	2,12
1,2	1,65	1,74	1,83	1,93	2,02	2,11	2,2
1,3	1,71	1,81	1,9	2	2,09	2,19	2,28
1,4	1,77	1,87	1,97	2,07	2,17	2,27	2,36
1,5	1,83	1,94	2,04	2,14	2,24	2,34	2,44
1,6	1,89	2	2,11	2,21	2,32	2,42	2,53
1,7	1,96	2,06	2,17	2,28	2,39	2,5	2,61
1,8	2,02	2,13	2,24	2,35	2,46	2,58	2,69
1,9	2,08	2,19	2,31	2,42	2,54	2,65	2,77
2	2,14	2,26	2,38	2,5	2,61	2,73	2,85
2,1	2,2	2,32	2,44	2,57	2,69	2,81	2,93
2,2	2,26	2,39	2,51	2,64	2,76	2,89	3,01
2,3	2,32	2,45	2,58	2,71	2,84	2,97	3,1
2,4	2,38	2,51	2,65	2,78	2,91	3,04	3,18
2,5	2,44	2,58	2,71	2,85	2,99	3,12	3,26
2,6	2,5	2,64	2,78	2,92	3,06	3,2	3,34
2,7	2,57	2,71	2,85	2,99	3,14	3,28	3,42
2,8	2,63	2,77	2,92	3,06	3,21	3,36	3,5

Skidding distance l, km	Difficulty ρ of skidding ways						
	0,9	0,95	1	1,05	1,1	1,15	1,2
	Skidding index						
2,9	2,69	2,84	2,99	3,14	3,28	3,43	3,58
3	2,75	2,9	3,05	3,21	3,36	3,51	3,66
3,1	2,81	2,97	3,12	3,28	3,43	3,59	3,75
3,2	2,87	3,03	3,19	3,35	3,51	3,67	3,83
3,3	2,93	3,09	3,26	3,42	3,58	3,75	3,91
3,4	2,99	3,16	3,32	3,49	3,66	3,82	3,99
3,5	3,05	3,22	3,39	3,56	3,73	3,9	4,07
3,6	3,11	3,29	3,46	3,63	3,81	3,98	4,15
3,7	3,18	3,35	3,53	3,7	3,88	4,06	4,23
3,8	3,24	3,42	3,6	3,78	3,96	4,14	4,31
3,9	3,3	3,48	3,66	3,85	4,03	4,21	4,4
4	3,36	3,54	3,73	3,92	4,1	4,29	4,48

Table 4b

Cutting Index (CI) for Different Site Conditions

Difficulty of harvesting site	0.9	0.95	1	1.05	1.1	1.15	1.2
Cutting index	0.88	0.93	0.98	1.03	1.08	1.13	1.18

Table 4c

Correction Percents

Percent of broadleaved tree species	Correction percent, P_1	Percent of large wood	Correction percent, P_2	Percent of small wood	Correction percent, P_3
10	1	10	-3	10	2
20	2	20	-6	20	4
30	2	30	-10	30	5
40	3	40	-13	40	7
50	4	50	-16	50	9
60	5	60	-19	60	11
70	6	70	-22	70	13
80	6	80	-26	80	14
90	7	90	-29	90	16
100	8	100	-32	100	18

The correction percent P is the algebraic sum of P_1, P_2 and P_3.

Appendix No 1

Difficulty of cutting site, ε

slope	*mean diameter*	*growing stock*	*crown length*	*obstacles*	*contribution*
degrees	*cm*	*m^3/ha*	%	%	
0 – 5	> 40	> 185	0 – 35	0 – 30	0,168
6 – 10	37 – 40	156 – 185	36 – 65	31 – 50	0,184
11 – 20	33 – 36	126 – 155	66 – 85	51 – 70	0,200
21 – 30	29 – 32	96 – 125	> 85	> 70	0,216
31 – 45	25 – 28	66 – 95			0,232
> 45	21 – 24	36 – 65			0,248
	17 – 20	0 – 35			0,264
	13 – 16				0,280
	0 – 12				0,296

The difficulty of site ε is the sum of the contributions of all the five pertinent parameters.

Difficulty of skidding ways, ρ

category of skidding ways	difficulty
downhill skidding on slopes <16° , uphill skidding on slopes < 4°	0,88
downhill skidding on slopes > 16°, uphill skidding on slopes < 4°	1
uphill skidding on slopes > 4° or stony or rocky ground on 50% of the distance	1,18

If the difficulty of skidding is not constant, a weighted mean is to calculate.

Appendix No 3

Mean values in forest harvesting in Bulgaria

Assortments and costs BGL/m^3		large timber	middle timber	small timber	piled wood	mean	%
cutting	BGL/m^3	4,4	7,0	9,4	7,8	6,9	**100**
conifers	BGL/m^3	**4,2**	**6,7**	**8,6**	**7,3**	6,0	100
broadleaved	BGL/m^3	**4,5**	**7,2**	**9,8**	**8,1**	7,4	100
Fixed costs for skidding	BGL/m^3	5,9	8,1	8,1	7,0	7,1	**102**
conifers	BGL/m^3	**5,6**	**7,6**	**7,6**	**7,1**	6,8	113
broadleaved	BGL/m^3	**6,0**	**8,4**	**8,4**	**7,0**	7,2	98
Kilometer costs for skidding	BGL/m^3	3,7	5,4	5,9	5,0	4,7	**68**
conifers	BGL/m^3	**2,7**	**4,7**	**5,2**	**4,9**	4,0	67
broadleaved	BGL/m^3	**4,2**	**5,7**	**6,2**	**5,0**	5,1	69
Total for 1 km skidding	BGL/m^3	9,6	13,5	14,0	12,0	11,8	171
conifers	BGL/m^3	8,3	12,3	12,8	12,0	10,7	180
broadleaved	BGL/m^3	10,2	14,1	14,6	12,0	12,3	167
Total, to cut and skid 1 km	BGL/m^3	14,0	20,5	23,4	19,8	18,7	271
	%	**100**	**147**	**168**	**142**		
conifers	BGL/m^3	12,5	19,0	21,4	19,3	16,7	280
broadleaved	BGL/m^3	14,7	21,3	24,4	20,1	19,7	267

The mean values have been calculated for following typical distributions of assortments in the sold timber, which hold according to the forestry statistic since decades.

Conifers	40	40	10	10
Broadleaved	20	20	10	50

Conifers	33
Broadleaved	67

Appendix No 2

Assortment tables for pine stands

mean diameter	I	II	III	IV	V	VI	piled wood	harvest waste	bark
cm	%	%	%	%	%	%	%	%	%
									1 quality class
6					2	52	11	6	29
10					45	19	8	4	24
14		1	10	12	42	3	8	4	20
18		13	20	17	18		10	4	18
22	2	32	19	10	5		11	3	18
26	9	41	13	4	1		11	3	18
30	18	42	7	1			11	3	18
34	29	36	2	1			11	3	18
38	39	28	1				12	3	17
42	47	20	1				12	3	17
46	54	14					12	3	17
50	59	9					12	3	17
54	62	6					12	3	17
58	64	4					12	3	17
									2 quality class
6					2	47	16	6	29
10					39	16	17	4	24
14			8	10	37	3	18	4	20
18		11	17	14	15		21	4	18
22		27	17	8	5		22	3	18
26	7	34	11	4	1		22	3	18
30	14	36	6	1			22	3	18
34	24	30	2	1			22	3	18
38	33	23	1				23	3	17
42	40	16	1				23	3	17

mean diameter	I	II	III	IV	V	VI	piled wood	harvest waste	bark
cm	%	%	%	%	%	%	%	%	%
46	46	11					23	3	17
50	50	7					23	3	17
54	53	4					23	3	17
58	54	3					23	3	17
									3 quality class
6					1	20	44	6	29
10					17	7	48	4	24
14		1	4	4	15	1	51	4	20
18		5	8	6	6		53	4	18
22	1	11	7	4	2		54	3	18
26	3	15	5	2			54	3	18
30	7	15	3				54	3	18
34	11	13	1				54	3	18

definitions of the quality classes

quality classes	percent of construction wood stems
1	91 – 100
2	71 – 90
3	0 – 70

Definition of assortments

Sortenkategorie	Sortenklasse	Zopfdurchmessser	minimale Länge	Abschaftigkeit
		cm	m	cm/m
	I^a	50 – …	4	3
starkes Bauholz	I	30 – 49	4	3
	II	18 – 29	4	2.5
	III	15 – 17	3	2
mittleres Bauholz	IV	12 – 14	3	2
	V	8 – 11	3	2
	VI	3 – 7	2	1.5
schwaches Bauholz				