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Determining the value of standing timber for harvest planning optimization

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Abstract. Forest managers conducting sustainable forest management are guided by the principles of sustainable use of natural resources, which involve the need for long and short-term planning in organizational units of the State Forests. Plans often differ from reality by the time individual treatments and cuts are to be performed. For economic reasons, it is important to optimize harvest planning, not only focusing on the volume of timber to be harvested, but also the price differences of individual tree species and sort types of wood.

The purpose of this study was to present methods evaluating standing timber and to assess their usefulness in optimizing the harvest volume using linear programming.

Stands designated to be cut were evaluated using transaction value methods, i.e. "the stumpage value method" M1, the "consumption value" method M2, as well as the net present value (NPV) method M3. The research material was obtained from the State Forests Information System (SILP) for the Marcule Forest District covering the years 2014–2018. The stand values were determined at the beginning and end of the 10-year planning period.

We observed that the stand value (standing timber) differed significantly between method M2 as compared to method M1. The value of stands determined by method M3, on the other hand, decreased as the discount rate increased.

In the process of optimizing the selection of stands for felling, economic criteria should also be taken into account and this is a direct measure of obtainable standing timber in terms of the cutting possibility in the given planning period. In stands where one species dominates, a simplified method of determining the value (M1) can be used, whereas in stands with significant species diversity, method M2 provides a significantly more accurate value for the cutting timber. However, if harvest volume optimization using linear programming methods is to take longer time periods into account, e.g. 30 years (three 10-year economic planning periods), the most reasonable method for determining the value of stands is the net present value method M3.

Keywords: forest valuation, harvest planning, stumpage value, net present value, consumption value

1. Introduction

The forest as a complex ecosystem has many functions, including a productive one by providing supply of wood raw material. Sustainable forest management requires all forest functions to be taken into account, with attention paid to the location of stands, their surrounding areas, species-age structure, health and other characteristics. The system regulating the use of managed forests in accordance with the Forest Management Instruction (IUL 2012) currently in force is based on selecting the optimal cut volume based on maturity of the stand to be cut, which is related to felling age and the size of the cut's average age, assuming that the average age of the holding after completion of the allowable cut will remain at the same level. The size of an allowable cut directly depends on the share and relation between the number of felling, near-felling and pre-felling stands. The lack of a commonly accepted and universal method of determining stand maturity for felling indicates that this is still an undefined area of research in forest management. It is also a practical problem because for many decades, forest managers have been using more intuitive

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methods than the results of empirical data (Bednarski et al. 2016) when establishing the queue of stands for cutting. Taking into account the current reality of the broadly understood context surrounding this issue, an economic criterion should be introduced as an additional one to be considered (Piekutin and Skreta 2012). It seems justified to take into account the value of wood raw material that can be obtained at the time of felling in the process of optimising stand harvesting (Płotkowski et al. 2016). When managing forests in compliance with all legal regulations in force and planning management activities for successive years, forest districts must maintain the revenues and costs of their operations at an appropriate level and in proper correlation. The characteristics of the economic conditions of forest management and a forecast of the expected financial results prepared in the forest management plan include, among others, an estimated prediction of expected financial results (Wysocka-Fijorek 2015). Annual planning is one of the most important tasks of forest management. It is to guarantee the proper implementation of material and financial plans in the forest district, while simultaneously caring for the condition of the stands and the development of wood resources. The aim should be to improve methods and reduce their labour intensity, while increasing the accuracy of annual planning at the level of the forest district (Wójcik 2013). Studies have shown (Borecki et al. 2004; Nowak 2004; Pawlak 2008) that the precisely prepared annual plan in many cases differs from the values obtained at the stage of individual treatments and cuts. These discrepancies occur both in total acquisition and, to a greater extent, the volume from species and specific assortments. It seems important not only to strive to more evenly distribute the volume of harvested wood in successive years, but also, above all, to obtain revenue from the sale of harvested raw material, taking into account the price differentiation of individual tree species and types of assortments. Perceiving the economic criterion in the context of optimising the amount of harvested wood will allow for a flexible approach in the event a response is needed to a changing economic situation in the wood market, limited by the demand for a specific group of assortments. Moreover, taking into account the dynamically changing weather conditions in Poland over the last few years (long-term droughts, lack of snow cover), it should be expected that a number of catastrophic phenomena will occur, which could result in the cessation of stand cutting by forest holdings for particular assortments lacking demand at a given time.

The aim of this study is to present selected methods of estimating the value of wood raw material in the stands and to assess their usefulness in optimising the size of the felling operation, taking into account the linear programming method.

2. An overview of selected methods for determining stand values

Each day, a number of situations are faced in business practice, whose solutions require determining simultaneously the value of all or specific elements of the forest environment, including stands (Zając and Świętojański 2002; Zydroń et al. 2007; Zając 2013).

Historically, empirical methods of estimating stand value were developed in reaction to the criticism of static methods (based on percentage accounting and profit and loss forecast accounting), of which Glaser is considered their principal author (Szramka 2018). Depending on the age of the appraised stand, the methods of incurred cost, sale value or expected value were adopted (Partyka and Trampler 1973; Marszałek and Podgórski 1978; Partyka and Parzuchowska 1993; Zając and Świętojański 2001; Klocek and Płotkowski 2009; Zając 2013; Szramka 2018). The incurred cost method (reproduction cost) is used for young stands that do not yet have a use value. The sale value method is applied to mature stands that have a use value. This method calculates the value of the stand based on the income that can be obtained from the harvesting and sale of the produced assortments. Stumpage sales value is the sum of the products of the value of individual assortments (according to sales prices) and the volume share of these assortments (Hauling 2013). The expected value method is used to estimate intermediate-aged stands using reduction coefficients, taking into account, e.g. the quotient of the square of the stand age to the square of the stand's felling age. These methods have been used to develop stand value tables for particular types of forest trees according to their age and site index class (Partyka and Parzuchowska 1993; Zając 2013; Zając et al. 2014). Several versions of stand value index tables have been developed, which have improved and reduced the workload of stand valuation. However, by using stand value index tables, the average value for the whole country is obtained (Szramka 2016; Zygmunt et al. 2018). Cymerman and Nowak (2017) emphasise that the valuation of forest stands in free market trading is not regulated by law, and the principles of valuing a stand are defined in the interpretive note V.6 (PFSRM 2003). According to the standard V.6, when determining the market value of stands of near-felling, felling and older age, their total volume and the shares of assortments in the timber volume determined on the basis of a stock survey should be taken into account. When determining the timber volume of near-felling, felling and older stands, the method of measuring total diameter at breast height of the trees in that stand should be used (PFSRM 2003).

Currently known methods of estimating stand value are: cost value method (reference to the past), market value method (reference to the present) and income value method (investment value – reference to the future) (Klocek and Płotkowski 2009). Income value methods can be divided into methods by profit and loss forecast value and expected value. The income value in forestry is synonymous with market value, as it reflects the level of all net income from the stand (Zając 2013). A forest stand is an income-generating property (real estate); therefore, the most commonly used method of the valuation of forest properties, when there is no data on their turnover on the market, is currently the so-called investment method. A characteristic feature of the investment method is the discounting or prolongation of net cash flows (Zając and Świętojański 2001). 'Discounting' means reducing a certain nominal amount, and the discount rate is used to convert (import) the assumed future cash flows into the present value (Zydroń et al. 2012). 'Prolongation' means determining the future value of money (using a specified interest rate). Determining the updated value, called present value, consists in discounting future values and prolonging the value of past cash flows to a specified age (the age of the stand being valued) (Zając 2013). According to other authors, the valuation methods for standing trees in felling stands can be divided into two categories (European Communities 2002), i.e. transaction value methods that use the price obtained from observed transactions in the whole period to the resource's asset components, and net present value (NPV) methods that are based on calculating the value (or change in value) of the asset by the present value of future net profits. Under the transaction value method, the price per unit of raw material is derived from observed transactions and is referenced to the value of the entire inventory or change in inventory. The price of wood/m^3 used in this method can be the price of stumpage (if available) or the price of felled, bucked and stacked wood on the transport route. Where data on the stumpage value (standing trees) are not available, they can be determined on the basis of available prices for felled timber and prepared for delivery, deducting the costs of harvesting, skidding and possible longer storage. The exact calculation of costs is complex, e.g. for skidding, taking into account, among others, tree species, length of skidding, slope inclination, type of land or the skidding agent used (semi-suspended skidding, forwarders). Therefore, the use of generalisations is allowed, in which the stumpage value (standing timber) is defined by applying the available price of felled wood. The stumpage price determined in this way is used to calculate the value of whole stands or to change their value over time, e.g. when they are being utilised. Two variants are distinguished in the transaction value method used for stand valuation: the 'stumpage value' method and the 'consumption value' method.

3. Study material and methods

The study material consists of the following data from the State Forests Information System (SILP) for the Marcule Forest District, in particular: (1) taxation descriptions of selected stands (felling) as of 1 January 2017 (Table 1); (2) reports on the implementation of logging plans including the volume of harvested wood by type and assortment by cutting position and activity groups; (3) sum of volume and value of wood sold by type–assortment group and (4) harvesting and skidding costs. The data for points (2–4) were compiled annually and cover 2014–2018.

The average costs of harvesting and skidding wood in the Marcule Forest District for 2014–2018 are presented in Table 2. The costs of harvesting and skidding are weighted by the volume of respectively harvested and skidded timber in the given year in the whole forest district, regardless of the type of harvesting and skidding technology used and other parameters.

The following methods were proposed for determining the value of wood raw material in the felling stands:

1) The 'stumpage value' method M1

This method calculates the value of raw material per stem as the product of the average volume of a given stand and the average price obtained from the sale of 1 m^3 of wood in the entire forest district in 2014–2018, less the average costs of harvesting and skidding in this period. The price of the wood is weighted by the volume of sold raw material (in 2014–2018), regardless of the type and assortment of wood.

The value of wood raw material was determined according to the formula:

$$W_n = V_n\,(C - K) \quad \text{[PLN/ha]} \qquad (1)$$

where
W_n is the value of wood raw material per 1 ha in stand n,
V_n is the average stand volume of n (m^3/ha),
C is the average price obtained from the sales of 1 m^3 of wood in the forest district in the last 5 years and
K is the average cost of harvesting and skidding 1 m^3 of wood in the last 5 years.

2) The 'consumption value' method M2

The stumpage value calculated with this method is the product of the average volume of each tree species in the stand, the average price obtained from the sale of 1 m^3 of a specified given assortment and species of timber, and the percentage share of the assortment groups of each species minus the average costs of harvesting and skidding. The average price of a given species and assortment (groups of assortments) was calculated as the weighted average of the quantity of the assortment sold. In this paper, the assortments were divided into seven groups using the nomenclature adopted in forest practice, i.e. large-size wood of quality classes A and B as the so-called 'class' wood without division into thickness classes; large-size wood of quality classes C

Table 1. Taxation features of selected stands with different species compositions in the Marcule Forest District in 2017

Location	Species*	Share [%]	Age [years]	Tree density index	Gross volume** [m^3/ha]
22 i	BRZ	9	80	0.7	212
22 i	SO	1	80	0.7	27
28 l	SO	10	116	1.0	368
72 k	BRZ	10	57	0.9	200
122 c	OL	10	68	0.7	167
128 c	DB	8	90	0.8	257
128 c	SO	2	90	0.8	71
128 k	DB	10	80	0.8	362
136 f	BRZ	6	75	0.7	161
136 f	SO	4	75	0.7	120
221 l	DB	6	102	0.9	189
221 l	BRZ	2	82	0.9	57
221 l	SO	2	82	0.9	63

* SO – pine; BRZ – birch; OL – alder; DB – oak
** conversion from gross to net was adopted at the level of 0.82

Table 2. Unit average costs of cutting and logging in (PLN/m^3) in the Marcule Forest District in 2014–2018

Year	Cost of cutting	Cost of logging	Sum
2014	23.25	22.53	45.78
2015	22.01	21.53	43.54
2016	24.44	25.47	49.91
2017	26.86	26.61	53.47
2018	29.25	28.43	57.68
Average	25.16	24.91	50.08

Source: own elaboration

in the first, second and third thickness classes, respectively; large-size wood of quality classes D without division into thickness classes and medium-size wood covering all assortments except firewood and wood of quality class S4, whose price is decidedly lower.

The value of wood raw material was determined according to the formula:

$$W_n = \sum_{i=1}^{l} \sum_{s=1}^{m} V_{ni}\, 0{,}01 U_{si}\, C_{si} - V_n K \quad \text{[PLN/ha]} \qquad (2)$$

where
V_{ni} is the volume of species i in stand n,
U_{si} is the share (%) of assortment group s in the total volume of species i (Table 3),
C_{si} is the price obtained from the sale of 1 m^3 of wood of assortment s for type (species) i (Table 4),
l is the number of species in stand n and
m is the number of assortment groups (seven groups in this study).
Other symbols are designated as in formula (1).

3) NPV method M3

The NPV method calculates the value of forest assets according to the present value of future net economic benefits. Basically, a future income and cost model and a discount rate (Bettinger et al. 2017) are required to determine this value. Depending on the complexity of the model and how the discount rate is determined, there are several options for determining the present value. In the simplest one, the discount rate is determined externally, e.g. as a result of consulting forestry experts; it is accepted that the allowable level of the discount rate for forest assets in Europe is between 1% and 2.5% (European Communities 2002). In the case of long-term capital, e.g. a tree stand, a discount rate of 1%-3% is usually assumed (Podgórski and Zydroń 2001; Zydroń et al. 2012). According to other authors, the discount rate should be between 2% and 3% (Adamowicz 2018) and should not exceed 7% for stands (Grege-Staltmane et al. 2010). In turn, Bullard and Straka (2011) indicated that the level of the discount rate for wood resources (products) should be lower than the one used in companies to calculate a specific investment. Forestry investments are long term and require taking into account certain risks and uncertainties relating to this (Samuelson 1995; Holopainen et al. 2010).

This method calculates the value of wood raw material as the value determined according to the M2 method, which is then discounted at the accepted rate, i.e. 1%, 2.5% and 5%.

The value of wood raw material was determined by the formula:

$$W_{NPV} = (\sum_{i=1}^{l} \sum_{s=1}^{m} V_{ni}\, 0{,}01 U_{si}\, C_{si} - V_n K) \,/\, (1 + 0{,}01r)^t \quad [\text{PLN/ha}] \quad (3)$$

where
r is the discount rate (1%, 2.5%, 5%, respectively) and
t is the time period.
Other symbols are designated as in formulas (1) and (2).

The value of the stands was determined at the beginning and end of the 10-year economic planning period. The calculations performed with formula (3) assume that average prices are fixed at the beginning and end of the planning period and do not change. The stand volume at the end of a 10-year economic planning period was determined by adding the growth volume increment of the stand to the volume at the beginning of the current period.

4. Results

The dominant type of wood in the Marcule Forest District is pine, which accounted for 89.0% of the total wood harvested by logging in 2014–2018. Oak wood constituted 5.3%, hornbeam wood 1.3% and birch wood 1.0%, while the share of other species did not exceed 1%. WC0 class timber intended for sawmills prevailed in the assortment structure, its share depending on the type ranged (total of WC01, WC02, WC03) from 75.4% for pine to 7.7% for oak (Table 3). Hornbeam wood was produced only in medium-sized assortments, in which the share of firewood dominated (75.2%).

The price of wood weighted by the volume of sold raw material (in the period 2014–2018) averaged 219 PLN/m^3, regardless of the wood type and assortment (Table 4). De-

Table 3. The share of assortment groups by type (species) of wood in 2014–2018

Type of wood	Assortment share [%]							Sum [100%]
	S	S4	WAB0	WC01	WC02	WC03	WD	
BRZ	9.9	51.0	-	2.9	10.0	2.4	23.8	100
DB	32.5	41.7	0.5	0.2	2.2	5.3	17.6	100
GB	24.8	75.2	-	-	-	-	-	100
JD	22.0	11.9	0.6	4.0	19.4	38.9	3.2	100
OL	9.8	51.9	0.4	3.3	6.8	2.6	25.2	100
SO	7.1	5.1	6.4	9.9	50.2	15.3	6.0	100
Average	9.3	10.0	5.8	9.0	45.1	14.4	6.4	100

*WAB0 – large-size wood of quality classes A and B; WC01 – large-scale quality wood class C in the first thickness class; WC02 – large-scale quality wood class C in the second thickness class; WC03 – large-size wood of the quality class C in the third thickness class; WD – large-size wood of quality class D of all thickness classes; S – includes all sizes of medium-sized wood. except for S4; S4 – firewood; JD – fir; GB – hornbeam
Source: own elaboration

Table 4. Average wood prices [PLN/m³] by species type and assortment groups in 2014–2018

Type of wood	Group of assortments*							
	S	S4	WAB0	WC01	WC02	WC03	WD	Average
BRZ	140	136	270	202	222	244	178	153
DB	194	133	1772	366	509	691	374	229
GB	157	148	–	–	–	–	–	150
JD	141	101	361	243	279	306	200	231
OL	128	98	293	180	259	332	202	129
SO	151	107	308	232	263	292	193	224
Average	152	119	314	232	263	301	212	219

* Explanations of symbols as in tables 1 and 3
Source: own elaboration

pending on the type, the price ranged from 129 PLN/m³ for alder to 231 PLN for fir. Depending on the assortment, the price ranged from 119 PLN for firewood to 301 PLN/m³ for third class sawmill (WC03) and 314 PLN for valuable wood (WA0 and WB0 together).

The value of wood raw material determined using the simplified M1 method according to formula (1) depends directly on the stand's abundance and the adopted average price of wood. For the selected example stands, this value ranges from 21,783.24 PLN/ha for alder stand 122 c with a net abundance of 137 m³/ha to 47,859.32 PLN/ha for pine stand 28l with a net abundance of 302 m³/ha (Fig. 1).

The M2 method allows us to determine the timber volume of wood raw material according to the type–assortment structure. In selected example stands, the largest amount of sawmill wood (227.2 m³/ha, total of WC01, WC02, WC03) is found in pine stand 28l, while the largest amount of medium-sized wood, except for class S4 (96.5 m³/ha), is found in oak stand 128 k (Table 5).

The value of the stands (wood raw material) determined by the M2 method according to formula (2) depends on the stand species composition and assortment structure and differs from the value of the raw material determined by the M1 method (Fig. 1). In stands with a significant share of birch (22 i, 72 k, 136 f) or alder (122 c), the value of the raw material determined by the M2 method is significantly lower compared to the value of those stands determined by the M1 method. When pine (28l) or oak (128 c, 128 k) dominates in the stand composition, the M2 method indicates higher stand values compared to the M1 method.

Stand values determined by the M3 method of discounting future income at the current moment (NPV) according to formula (3) are shown in Table 6. Stand values at the beginning of the period (column 2) and at the end of the period at a zero discount rate (column 3) are equal to those determined by the M2 method. The following columns (4–6) show the NPVs of the wood raw material at the end of the 10-year period at different discount rates (from 1% to 5%).

As the discount rate increases, the present value of the raw material that would be obtained at the end of the period decreases. The difference between the value of the stand at the beginning of the period and the present value that the

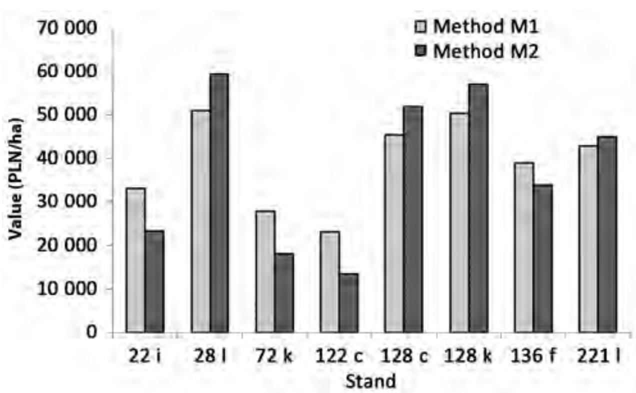

Figure 1. Value of wood raw material determined according to the M1 method and the M2 method in selected stands of the Marcule Forest District in 2017

Source: own elaboration

Table 5. Timber volume of assortments in selected stands in the Marcule Forest District in 2017

Stand	Species	Assortments [m³]							
		S	S4	WAB	WC1	WC2	WC3	WD	Total
22 i	BRZ	17.2	88.7	0.0	5.0	17.4	4.2	41.4	173.8
	SO	1.6	1.1	1.4	2.2	11.1	3.4	1.3	22.1
28 l	SO	21.4	15.4	19.3	29.8	151.3	46.1	18.1	301.4
72 k	BRZ	16.2	83.6	0.0	4.8	16.4	3.9	39.0	164.0
122 c	OL	13.4	71.1	0.5	4.5	9.3	3.6	34.5	136.9
128 c	DB	68.5	87.9	1.1	0.4	4.6	11.2	37.1	210.7
	SO	4.1	3.0	3.7	5.8	29.2	8.9	3.5	58.2
128 k	DB	96.5	123.8	1.5	0.6	6.5	15.7	52.2	296.8
136 f	BRZ	13.1	67.3	0.0	3.8	13.2	3.2	31.4	132.0
	SO	7.0	5.0	6.3	9.7	49.4	15.1	5.9	98.4
221 l	DB	50.4	64.6	0.8	0.3	3.4	8.2	27.3	155.0
	BRZ	4.6	23.8	0.0	1.4	4.7	1.1	11.1	46.7
	SO	3.7	2.6	3.3	5.1	25.9	7.9	3.1	51.7
Sum	BRZ	51.1	263.5	0.0	15.0	51.7	12.4	123.0	516.6
	DB	215.3	276.3	3.3	1.3	14.6	35.1	116.6	662.6
	OL	13.4	71.1	0.5	4.5	9.3	3.6	34.5	136.9
	SO	37.8	27.1	34.0	52.6	267.0	81.4	31.9	531.8
Total	m³	317.7	637.9	37.9	73.5	342.5	132.4	306.0	1847.9
	%	17.2	34.5	2.1	4.0	18.5	7.2	16.6	100.0

Explanations of symbols as in tables 1 and 3
Source: own elaboraton

stand will reach at the end of the period is important when deciding whether to designate a stand to be felled in a given economic period or leave it for the next one. If the increase in value (%) is greater than the interest that would be obtained after felling the stand, selling the wood and depositing the sales proceeds in a bank, the stand should be left for further cultivation to the next period. If the increase in value would be less than the achievable interest, from an economic point of view, the stand should be designated for felling in the current period.

In the analysed harvest at a 1% discount rate, only the stand 72 k shows a positive and greater than the assumed rate (4%) of increase of present value during the first 10-year period. This is a 57-year-old birch stand with relatively dynamic current growth. The remaining stands show a decrease in NPV at the end of the economic period – decreasing even more at higher assumed discount rates. A negative NPV increment is characteristic for older stands with lower growth dynamics. Due to the fact that the stands also perform non-productive functions, a negative NPV increment does

Table 6. The value of wood raw material determined according to (NPV) in selected stands of the Marcule Forest District in 2017 and 2027 (at the beginning and end of the planning period at various discount rates)

Stand	Value of wood raw material [PLN/ha]				
	year 2017	year 2027 discount rate [%]			
		0	1	2,5	5
22 i	23 389.73	24 988.49	22 621.75	19 520.97	15 340.77
28 l	59 339.14	63 084.80	57 109.85	49 281.74	38 728.59
72 k	17 957.67	20 585.62	18 635.90	16 081.46	12 637.79
122 c	13 380.24	14 552.23	13 173.95	11 368.18	8 933.81
128 c	51 892.95	56 138.36	50 821.33	43 855.20	34 464.09
128 k	56 949.16	62 126.35	56 242.18	48 533.01	38 140.19
136 f	33 773.46	36 423.70	32 973.90	28 454.14	22 360.99
221 l	45 118.63	48 235.41	43 666.89	37 681.43	29 612.36

Source: own elaboration

not automatically mean that the stand is qualified for felling. Instead, it can be a helpful tool for deciding on the order in which stands are to be designated for felling, up to the level of a specific cut, taking into account other factors, including the multifunctionality of the forest.

5. Summary and conclusions

The methods presented in this paper for determining the value of wood raw material in stands can be used in the processes of optimising the selection of stands for felling. The choice of the method should depend on the forestry unit, which is subject to regulations, and especially on the age and species structure of the stands. The M1 method can be applied to simple vertical stands, stands of a single age and species, in managed forest holdings. The disadvantage of this method is that it does not take into account either the tree species or the prices of individual assortment groups, which significantly impact the final stumpage value. On the other hand, the M2 and M3 methods take into account the differences among the assortments for individual species in the stand and the percentage of species in the total volume of the stand. However, they are somewhat generalised due to the structure of already performed harvests and the existing assortment–species system, which may differ with respect to stands that remain to be felled in the future (European Communities 2002). The M3 method, which additionally involves discounting, should be applied in optimisation models that also use an economic criterion, as this takes into account the change in the value of future income from the forest. As a rule, several successive economic planning periods are covered, e.g. 3-, 4-, 5- or 10-year periods in the case of methods based on linear programming (Marušák and Kašpar 2015).

The following conclusions can be drawn from the research conducted:

1. Both natural and economic criteria should be taken into account when determining the size of a felling operation, the direct measure of which is the value of the wood raw material that can be harvested in the stand analysed for felling potential in a given planning period.

2. In forest districts with one dominant species and low habitat diversity, a simplified M1 method may be used to determine the value of felling stands. Both the type–assortment structure and the price of wood will be similar in individual stands.

3. In forest districts with a significant species diversity of stands, the M2 method, which takes into account the type–assortment structure of individual stands, is better suited to determine the value of felling stands.

4. The M2 method makes it possible to determine the volume of wood raw material in individual stands, which is important and allows the economic situation (downturn) to

be taken into account for specific assortments when determining the stands to be felled in annual planning.

5. The M3 method can be used to determine stands for felling, especially in forests with a dominant production function.

6. In optimising stand selection for felling using the linear programming method, which often takes into account a longer time horizon, e.g. 30 years (three 10-year economic planning periods), the M3 method of NPV seems to be the most well-founded method for determining stand values.

Conflicts of inte est

The authors declare no potential conflicts of interest.

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References

Adamowicz K. 2018. A review of selected methods to determine the economic value of forest: Polish research, w: New perspectives in forest science. *IntechOpen*, 72–85. DOI 10.5772/intechopen.72907.

Adamowicz K. 2018. The unresolved problem of determining the forest interest rate. *Folia Forestalia Polonica, Series A-Forestry* 60(2): 122–130. DOI 10.2478/ffp-2018-0012.

Bednarski K., Miścicki S. 2016. Kolej rębu drzewostanów sosnowych według kryteriów ekonomicznych. *Sylwan* 160(3): 197−206. DOI 10.26202/sylwan.2015095.

Bettinger P., Boston K., Siry J.P., Grebner D.L. 2017. Forest Management and Planning. Academic Press. ISBN 9780128094761.

Borecki T., Wójcik R., Standio R., Jaszczyk J., Krzyżanowski J., Lecko R., Stępień E., Nowakowska J., Orzechowski M., Kweczlich I., Podgórski K., Siembida A., Sierdziński Z., Czarnecka R., Nowak M. 2004. Nowa koncepcja określania wielkości użytkowania rębnego i przedrębnego w planowaniu rocznym. Maszynopis dokumentacji sprawozdania końcowego dla DGLP.

Bullard S.H., Straka T.J. 2011. Basic concepts in forest valuation and investment analysis. (Edition 3.0.). Proceda Education and Training, Auburn, AL, USA. ISBN 0-9641291-2-4.

Chapman H. 1914. Forest Valuation. Stanbope press. Boston, 21–34.

Cymerman R., Nowak A. 2017. Wycena lasów do różnych celów w świetle obowiązującego prawa. *Acta Scientiarum Polonorum Silvarum Colendarum Ratio et Industria Lignaria* 16(2): 95–106.

Duerr W.A. 1960. Fundamentals of Forestry Economics. McGraw-Hill Book Company. New York. USA, 579 s.

European Communities. 2002. EU official publications. IEEAF – The European Framework for integrated environmental and economic accounting for forests. Annex 3 – valuation methods, 101–104.

Grege-Staltmane E. Tuherm H. 2010. Importance of discount rate in Latvian Forest Valuation. *Baltic Forestry* 16(2): 303–311.

Holopainen M., Mäkinen A., Rasinmäki J., Hyytiäinen K., Bayazidi S., Vastaranta M., Pietilä I. 2010. Uncertainty in forest net present value estimations. *Forests*. 1: 177–193. DOI 10.3390/f1030177.

IUL 2012. Instrukcja urządzania lasu. Centrum Informacyjne Lasów Państwowych, Warszawa, 652 s. ISBN 978-83-61633-66-2

Klocek A., Płotkowski L. 2009. Wartość lasu w rachunkach narodowych, rachunku wyników i bilansie gospodarstwa leśnego. Maszynopis. Warszawa, 1–43.

Marszałek T., Podgórski M. 1978. Zarys ekonomiki leśnictwa. PWRiL, Warszawa, 351 s.

Marušák R., Kašpar J. 2015. Spatially-constrained harvest scheduling with respect to environmental requirements and silvicultural system. *Forestry Journal* 61: 71–77. DOI 10.1515/forj-2015-0015.

Nota interpretacyjna standardu V.6. Wycena nieruchomości leśnych i zadrzewionych. 2003. Warszawa, Polska Federacja Stowarzyszeń Rzeczoznawców Majątkowych (PFSRM).

Nowak J. 2004. Analiza struktury sortymentowej w planowaniu rocznym w Nadleśnictwie Lubliniec. Maszynopis pracy inżynierskiej. Katedra Urządzania Lasu, Geomatyki i Ekonomiki Leśnictwa, SGGW.

Partyka T., Trampler T. 1973. Opracowanie tablic wartości drzewostanów. Dokumentacja Instytutu Badawczego Leśnictwa, Warszawa: 1-13.

Partyka T., Parzuchowska J. 1993. Metodyka wartościowania lasu oraz poszczególnych jego składników. *Sylwan* 8: 29–40.

Pawlak A. 2008. Analiza rozmiaru Użytkowania na potrzeby wykorzystania informacji do planowania rocznego w Nadleśnictwie Mirosławiec. Maszynopis pracy inżynierskiej. Katedra Urządzania Lasu, Geomatyki i Ekonomiki Leśnictwa, SGGW.

Piekutin J., Skreta M. 2012. Ekonomiczny wiek rębności drzewostanów sosnowych. *Sylwan* 156(10): 741–749. DOI 10.26202/sylwan.2011109.

Płotkowski L., Zając S., Wysocka-Fijorek E., Gruchała A., Piekutin J., Parzych S. 2016. Economic optimization of the rotation age of stands. *Folia Forestalia Polonica, A-Forestry* 58(4): 188–197. DOI 10.1515/ffp-2016-0022.

Podgórski M., Zydroń A. 2001. Możliwości wykorzystania zmodyfikowanego rachunku leśnej stopy procentowej do wartościowania lasu i jego składników. *Prace Komisji Nauk Rolniczych i Nauk Leśnych. Polskie Towarzystwo Przyjaciół Nauk*: 83–89.

Samuelson P.A. 1995. Economic of forestry in an evolving society. *Journal of Forest Economics* 1(1): 115–146.

Szramka H. 2016. Przegląd metod szacowania wartości lasu. Referat wygłoszony na VI Konferencji ekonomiczno-leśnej „Wycena nieruchomości leśnych i ich funkcjonalnych części" 18-21 październik 2016, Kołobrzeg.

Szramka H. 2018. Przegląd metod szacowania wartości lasu. *Nauka Przyroda Technologie* 12(4): 325–339.

Ustawa o lasach. 1991. Ustawa z dnia 28 września 1991 r. o lasach. Dz.U. 1991 nr 101 poz. 444.

Wójcik R. 2013. Obrębowa metoda szacowania użytków trzebieżowych w planowaniu rocznym. Rozprawy naukowe i monografie. Wydawnictwo SGGW. Warszawa, 7–8.

Wysocka-Fijorek E. 2015. Zagadnienia ekonomiczne w planowaniu urządzeniowym. *Sylwan* 159(10): 872–879. DOI 10.26202/sylwan.2015066.

Zając S. 2013. Wartościowanie lasu w teorii i praktyce. Konferencja „Lasy jako czynnik rozwoju cywilizacji: współczesna i przyszła wartość lasów", Sękocin Stary, 1–22.

Zając S., Klocek A., Sikora A., Fronczak E., Gniady R. 2013. Nowelizacja tablic wskaźników wartości drzewostanów, stanowiących załącznik do rozporządzenia ministra środowiska z dnia 20 czerwca 2002 r. w sprawie jednorazowego odszkodowania za przedwczesny wyrąb drzewostanów. Dokumentacja końcowa tematu badawczego BLP-378.Instytut Badawczy Leśnictwa, Sękocin Stary, 1-57.

Zając S., Świętojański A. 2002. Podstawy metodyczne wyceny lasu. *Sylwan* 146(3): 5–20.

Zydroń A., Szafrański Cz., Korytowski M. 2012. Koncepcje określania wysokości leśnej stopy procentowej. *Sylwan* 156(5): 333–342. DOI 10.26202/sylwan.2011131.

Zygmunt R., Banaś J., Bujoczek L, Zięba S. 2018. Wartość zasobów drzewnych wybranych drzewostanów bukowych i jodłowych w Beskidach. *Sylwan* 162(9): 718–726. DOI 10.26202/sylwan.2018012.

Author's contribution

K.Z. – concept, collection of study material, literature review, methodology, calculations, text editing; J.B. – concept, methodology, text editing; A.K. – literature review, text editing

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