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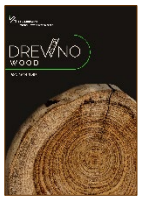

Application of Value at Risk Method to Assess Timber Selling Price Risk

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As organisations and economic markets continually evolve, it becomes essential to improve risk management skills on an ongoing basis. In this respect, it is particularly important to make practical use of all the tools available to identify and quantify risks. As with most entities, the most important tool for forest management is the timber selling price risk (TSPR). Economic practice shows that global markets experience very high volatility in this respect. The awareness of some popular techniques to understand the nature of individual risks by properly identifying their impact on the functioning of the organisation is currently increasing in importance. One of these techniques is the Value at Risk (VaR) method, which was used in this study to measure TSPR in 38 timber-selling economic entities. The aim of this article is to examine the concept of TSPR estimation using the VaR method adopted in the methodology by implementing the main VaR assumptions in the Polish forest economy in order to improve the methods of quantification of market risk in forestry, taking into account the impact of the sales volume and trade pattern of wood species on TSPR. The article demonstrates that the application of the VaR method can be an auxiliary tool in the TSPR management process. It is noted that this method can be a basic tool to ascertain the degree of exposure to risk and that the structure of commercial classes of timber is important. Using VaR, the relationship between the level of generated revenue and TSPR as well as between the assortment structure and TSPR was identified and discussed. It is also shown that the class of timber had an impact on TSPR.

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Introduction

The risk management process, which has been successfully implemented in financial institutions and has been widely applied in general business economics, is still languishing in the forestry industry [Haimes 2004]. [1]One of the elements of this process is the quantification of risk that must be identified in advance [Jajuga et al. 2007].

According to Krysiak [2011], the quality of risk management by companies is directly correlated with better financial performance, confirming the validity of implementing a range of processes to neutralise the impact of risk on business operations. It is of utmost importance to identify the environment in which the business operates and all the factors that have a significant impact on the risk management process. The dynamics of change in the environment of an economic

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entity intensifies the pressure to adapt as quickly as possible to the changes taking place, but also places considerable pressure on the entity to make the most of its resources. The described situation has been defined in the literature as the market and resource paradox [de Wit and Meyer 2007].

With regard to the issue at hand, it is important to emphasise that there are fundamental differences between the rules governing conventional business and those observed in forestry as in forest management, non-economic factors largely determine the shape of the market [Adamowicz 2011]. Financial systems differ from forest ecosystems primarily in terms of the much higher, in the case of forestry, probability of occurrence and effects of natural hazards for which the spatial scale is the reference point [Hummel et al. 2008]. For this reason, all the natural consequences expressed in economic losses must be taken into account in management decisions and should therefore be incorporated into the risk management procedure. In the case of an integrated forest management process, this appears to be an extremely difficult challenge. Nevertheless, there are some risks in forestry for which the same mechanisms can be applied analogously to financial systems. This risk group includes TSPR. This risk has relatively the same relationships as, for example, most natural resources and industrial products. The type of risk described is mainly due to fluctuations in product prices in the sales markets. With regard to the research area, the timber market, where the price of timber is shaped, should be regarded as the core outlet. The variation in the direction and value of changes in timber sale prices in the timber market are determinants of the strength of TSPR. This is particularly important for organisations where revenue diversification is limited. In Poland, for example, more than 88.3% of the revenue of the Polish State Forests National Forest Holding (PGL LP) comes from the sales of timber [General Directorate of the State Forests 2022]. In addition, the price and thus TSPR can be influenced by a positive or negative foreign trade balance. The quality and class of timber, transparent forms of sales and transparent information also play an important role in the timber price formation process. The strength of the impact of TSPR depends on the sensitivity of the organisation to timber price fluctuations, i.e. the higher the sensitivity, the higher the risk in the area of business activities. Timber prices primarily reflect the current state of the economy, the current demand for different timber classes, as well as local conditions and linkages with other segments of the economy [Mohammadi Limaei 2011]. The literature distinguishes three key factors for the success of timber producers, to which Möhring and Wilhelm [2015] include: (I) the amount of timber produced sustainably, (II) the revenue that can be generated from the sales of timber, (III) the corresponding sustainable production costs.

The failure of process users to adequately identify the underlying risks of a particular business can lead to its complete uselessness and, in the worst case, to indisputably wrong decisions in key areas of strategic management. A rational forest owner should have the appropriate knowledge to choose the economic activity that is the most beneficial and profitable [Austin et al. 2020]. One of the elements of a proper management process is risk assessment with the VaR method as part of it. Butler [2001] argues that the main objective of the VaR model is to measure the maximum expected loss that an institution can incur over a particular period, assuming normal market conditions and at specified confidence levels. Choudhry [2006], on the other hand, takes the view that VaR represents the highest probable loss from market risk exposure.

The concept of VaR emerged in the 1980s, but it was not until JP Morgan made the method available free of charge in 1994 that it became widespread among commercial banks and businesses [Mentel 2011]. The method has also found favour in forestry. Wan et al. [2015] used this method to determine the role of US forestry assets in a mixed portfolio from a risk perspective. Conditional Value at Risk (CVaR) was used to account for risk when building a portfolio of Pinus radiata trees for operational plantation deployment, under hypothetical changes on the volume, modulus of elasticity, resin defects and lumber prices [Pinto et al. 2015]. Eyvindson and Cheng [2016], and also Eyvindson et al. [2018] proposed the use of the VaR method in the forest management planning process. Robinson et al. [2016] described a method of estimating the uncertainty of harvesting outcomes by analysing the historical yield to the associated prediction for a large number of harvest operations. Eyvindson and Kangas [2017] confirmed that VaR is a useful tool for integrating uncertainty estimates into the optimisation process of forest management activities. The literature also mentions the use of the VaR simulation method to generate the values of individual climatic indicators [Friedrich et al. 2021] as well as to verify risk factors in investments in timber plantations [Chudy et al. 2020]. Based on a literature analysis, it is reasonable to agree with Gong [1994], who argues that different forest management activities carry different risk exposures. Taking this into account, this article focuses mainly on quantification of the negative consequences of the materialisation of risks in the area of revenue generated from timber sales, and in particular on the determination of the value of extreme fluctuations in revenue, as well as the average

timber sale price based on historical data of the recovery of revenue from timber sales in particular years.

The attempt to estimate the value at risk in the context of wood sales revenues generated over the years by individual units, undertaken in this article, is the first proposal in Polish literature to implement the VaR method into the system of financial management conducted by forest farms. Estimated in the empirical part, the risk levels of timber selling prices expressed in the values of revenues and average selling prices of timber at risk are a valuable source of information for decision-makers, in particular with regard to the maximum possible decrease in revenues as a result of the realization of market risk in a given period. Thanks to the adopted research program, it was also possible to develop an innovative concept of grouping units in relation to the risk scale of timber sale prices accompanying their activity. At the same time, the authors prove that the Value at Risk methodology adopted in Polish forest management is an excellent starting point for its further improvement in order to deepen the area of knowledge about the quantification of market risk in forest management, as well as to expand the practical skills of its application to measure financial risk in forestry.

Research Methodology

In order to comprehensively analyse the value of sales at risk, data from monthly reports aggregating all the data of timber sales value (LPIO-9 report) for the period 2015-2018 covering a set of all 38 round timber selling entities in Poland (forest districts comprising the Regional Directorate of State Forests in Katowice) were used. It should be added that the received LPIO-9 reports contained data on an annual basis regarding, among others, the value of timber sold, directions of timber sales, the amount of timber sold, trade groups of timber sales. The average timber sale price resulting from the timber sales reports received from the entities for the period under review and timber sales revenue by year were used as the main product price risk indicators, while the volume of timber sales in quantitative terms was used as the main factor levelling standard deviation. In addition, the analysis was extended to include verification of the exposure to timber selling price risk for individual groups according to the qualitative and dimensional classification of timber.

The Value at Risk model is a statistical measure of variability and has been defined as the maximum loss which is likely to materialise with a predetermined probability over a period set by the model user.

The following procedure was adopted to estimate the maximum loss from market risk using the Value at Risk method: I) The market value of the products (timber) to be sold was determined; II) The variance and standard deviation were estimated based on the historical distribution of the margins obtained from the sale of the products (monthly data on the margins obtained from the sale of the products); III) The time horizon was determined for which the maximum loss would be estimated; IV) A confidence level was determined relating directly to the probability with which the calculation of the value at risk would occur; V) A probability distribution was developed for the value of historical margins based on standard deviation, variance, confidence level, time horizon; VI) The maximum loss was estimated by calculating the quotient of the value of cumulative distribution functions (in this case ~ 2.33) and the margins derived from product sales, and then multiplying the result again by the current market value of the product for sale at the date of calculation. The VaR was therefore written as the following equation:

$$\mathbf{P\ (W \leq W_0 - VaR) = \alpha}$$

where:
α – level of tolerance
W– value of the product at the end of the period, defined as a random variable
W0 – the current value of the product.

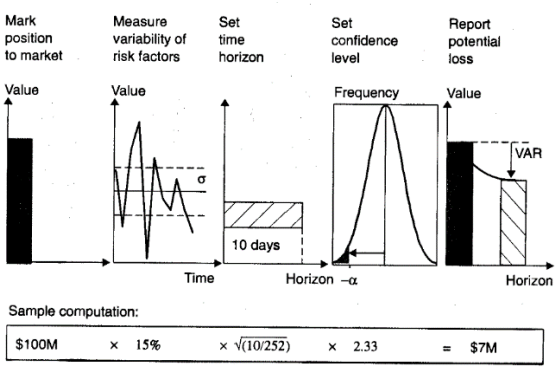

Fig. 1. Diagram of steps for calculating value at risk [Jorion 2007]

A risk management methodology developed in 1994 by J.P. Morgan known as RiskMetrics [Zangari and Longerstaey 1996] was used to estimate VaR.

The VaR concept presented in this paper is described in the literature as a historical VaR estimation methodology, in which the VaR calculation is based on a historical database and a user-adopted confidence level, for which the fifth percentile in the case of a 95% level of significance and the first percentile for the 99% level of significance are determined. The advantage of this method is the use of historical figures recorded by companies, and the reporting of extreme deviations from the expected value. The disadvantage, on the other hand, is that the data needed to estimate VaR has to cover a period of at least one year.

Based on the employed VaR estimation methodology, an attempt was made to assess the timber selling price risk using the historical VaR method. For this purpose, data was aggregated regarding revenues, average prices and the weight of timber sold by all the analysed entities in the period from 2015 to 2018. The average timber sale price for the entire analysed period was then estimated for individual entities, and the standard deviation was calculated together with the variance estimation for the historical timber sale data. A further step to make the analysis of the timber selling price risk more thorough was to distinguish separate assortment and quality groups in the aggregate data in the following order: large-diameter coniferous timber, large-diameter deciduous timber, medium-diameter coniferous and deciduous timber (S2A sorting). The breakdown was based on the criterion of the share of revenue from each timber trade group in total sales revenue from timber. After an analysis of the collected source data, a 95% confidence level and a one-year time horizon were adopted for the value at risk. At the stage of estimating the timber selling price risk, it was found necessary to eliminate the factor of fluctuation in the volume (m^3) of timber sold, which was a consequence of, among other things, a change in the forest management plan resulting in the implementation of a new 10-year plan, assuming an increase in the allowable cut. In the final analysis, it was decided that the financial effect of the impact of the timber selling price risk would be presented in two variants assuming respectively, price fluctuations resulting from the historical distribution of timber sale prices, and price fluctuations after eliminating the quantitative factor in the form of changes in the annual volume of timber sold during the analysed period.

Results by issues

The estimation of TSPR using the VaR method for individual forest districts is presented both in monetary terms, i.e. as the maximum decrease in the average timber sale price expressed in millions PLN – Table 1, and as a percentage value of the decrease in total revenue from timber sales when the maximum VaR level materialises – Table 3.

Table 1. Value at risk levels for individual forest districts

Entity No.	Entity name	Average revenue from timber sales in 2015-2018 period	VaR-annual	Annual VaR adjusted for annual changes in weight of timber sold	Four-year VaR for period under review
		HIGH RISK			
0206	Herby Forest District	12.55	3.11	2.32	5.27
0201	Andrychów Forest District	14.73	3.19	3.09	7.12
0205	Gidle Forest District	18.25	3.72	3.69	8.45
0226	Rybnik Forest District	19.69	3.97	3.83	8.75
0223	Prószków Forest District	23.59	4.72	4.33	9.85
0213	Kobiór Forest District	22.90	4.01	3.54	7.94
		MODERATELY HIGH RISK			
0225	Rudziniec Forest District	22.76	3.21	1.36	3.05
0227	Siewierz Forest District	9.57	1.34	1.26	2.80

0236	Węgierska Górka Forest District	20.92	2.33	1.99	4.49
0224	Rudy Raciborskie Forest District	17.00	1.89	1.66	3.67
0228	Strzelce Opolskie Forest District	19.86	2.18	2.04	4.52
0235	Wisła Forest District	6.12	0.64	0.62	1.37
		MODERATE RISK			
0218	Lubliniec Forest District	22.16	2.13	1.91	4.24
0238	Opole Forest District	28.39	2.67	2.39	5.29
0211	Kluczbork Forest District	22.15	2.05	2.04	4.55
0204	Brzeg Forest District	18.25	1.66	1.62	3.60
0229	Sucha Forest District	13.13	1.19	1.09	2.43
0237	Złoty Potok Forest District	14.02	1.17	1.03	2.30
0231	Turawa Forest District	24.50	2.01	1.95	4.36
0221	Olkusz Forest District	11.32	0.91	0.88	1.94
0233	Ujsoły Forest District	49.44	3.80	3.61	8.21
0210	Kędzierzyn Forest District	10.60	0.81	0.78	1.71
0212	Kłobuck Forest District	17.90	1.32	1.30	2.91
0214	Zawadzkie Forest District	18.29	1.34	1.30	2.90
0222	Prudnik Forest District	26.79	1.95	1.32	3.03
0208	Jeleśnia Forest District	19.04	1.35	1.27	2.86
0232	Tułowice Forest District	20.57	1.45	1.23	2.77
0207	Chrzanów Forest District	13.04	0.89	0.81	1.80
0215	Koniecpol Forest District	16.30	1.10	1.03	2.32
0219	Namysłów Forest District	19.60	1.27	1.25	2.80
0220	Olesno Forest District	20.37	1.21	1.18	2.67
0234	Ustroń Forest District	18.14	1.01	0.89	2.05
0217	Kup Forest District	20.84	1.08	1.06	2.40
		LOW RISK			
0230	Świerklaniec Forest District	16.29	0.75	0.72	1.64
0203	Brynek Forest District	11.26	0.46	0.42	0.96
0202	Bielsko Forest District	11.52	0.45	0.43	1.01
0216	Koszęcin Forest District	17.02	0.62	0.60	1.41
0209	Katowice Forest District	8.05	0.23	0.22	0.52

As can be seen from the data presented in Table 1, the Prószków Forest District has the highest annual value at risk in the period under review – 4.7 million PLN. In practice, this means that there is a 95% probability that the annual decrease in sales revenue caused by the materialisation of the risk will not exceed 4.7 million PLN. The Forest Districts of Gidle, Kobiór, Rybnik and Ujsoły should also be named among those with a high value of timber sales revenue at risk. At the other extreme are forest districts with a low timber selling price risk, such as Bielsko, Brynek, Katowice, Koszęcin or Wisła. Undoubtedly, this situation is influenced by the variation in terms of the total revenue generated from timber sales. The group of entities with a high timber selling price risk includes forest districts generating significant revenues as a consequence of both the volume of sales and the obtained annual average timber sale price. However, this is not the rule, as there are units such as the Kluczbork Forest District, which have a relatively low impact of risk with high revenue from timber sales. An interesting example of deviations in the scale of market risk is the Herby Forest District, where the value at risk without eliminating the change in sales volume is 3.1 million PLN, while after eliminating the quantitative factor of sales volume, the value drops to 2.3 million PLN, which confirms the significance of the issue of fluctuations in the mass of timber sold owing to an increase in allowable cut in the context of the correct application of the methodology for estimating the timber selling price risk. At this point, it is also worth emphasising that there are a few forest districts for which, in the period under review, the impact of changes in the volume of timber sold is negligible (Kluczbork and Gidle Forest Districts), and the scale of risk is derived solely from fluctuations in average timber sale prices.

In the analysis of the data on the exposure to the risk of average timber sale prices for the reviewed population of entities, it was considered reasonable to divide the forest districts according to the criterion of exposure to price risk based on the estimated potential decrease in the average price expressed in monetary units in a four-year perspective. Thus, the following risk levels were assumed (Table 2). It should be emphasized that the adopted division criterion is an original concept of grouping units in relation to the level of wood sale price risk and was prepared on the basis of the method of grouping similarities through a comparative analysis of the scale of the possible negative effects of risk realization for individual components making up the entire surveyed population.

Table 2. Price risk groups for forest districts

Risk level	**Deviation in PLN in a 4-year period**
high	>30
moderately high	>20
moderate	>10
low	<10

In the following steps, the analysed entities were assigned to the price risk groups presented above, taking into account the estimated deviations of average prices based on the VaR method. The obtained results indicate that, among the analysed entities, 40% have a high or moderately high exposure to timber selling price risk. The second part, 60%, is represented by forest districts with moderate and low risk, whose maximum decrease in the average sale price of timber in a four-year period does not exceed 20 PLN.

In order to more clearly illustrate both the impact of risk on the deviation in the average timber sale price and the percentage impact of the value at risk of loss on the total revenue, Table 3 is used to present the groups of forest districts in relation to the level of price risk involved in their operations. The highest percentage indicator of the value at risk was recorded in the case of the Herby Forest District; nonetheless, in this particular case, the value of this indicator was significantly influenced by the change in the volume of timber sales in the analysed period, which affects 1/4 of the scale of the estimated risk. On the other hand, taking into account the highest deviation of the timber sale price, after eliminating the sales volume factor, the forest district most exposed to this phenomenon was the Andrychów Forest District (a potentially maximal price drop of 47.52 PLN in a four-year perspective), just ahead of the Gidle Forest District (a drop of 42.38 PLN).

In comparison with the other forest districts, the entity that, despite generating significant revenue

from timber sales, has a very low level of price risk is the Koszęcin Forest District which, with an average annual revenue of 17 PLN million, achieved a value of 7 PLN potential deviation from the average price in the period under review, which, in annual terms, is a 1.80 PLN maximum decrease in the average price. By way of comparison, the Rudy Raciborskie Forest District, with an almost identical sum of average revenues, achieves an index of a potential decrease in the average timber sale price of 21.73 PLN and is in the group of forest districts with a moderately high level of risk. As in the foregoing discussion, it is also important to emphasise here the significant impact of the sum of revenues on the possibility of a potential loss resulting from a decrease in the average sale price of timber, but the example cited above shows that this is not the rule as in most cases the price drivers are more important than the sales volume itself.

Table 3. Percentage of value at risk in total revenue

HIGH RISK					
No.	**Entity name**	**% of average annual timber sales revenue**	**maximum change in total average timber sale price (in PLN)**	**maximum change in total average timber sale price after eliminating quantitative factor (in PLN)**	**impact of change in weight of timber sold over considered period**
0206	Herby Forest District	24.75%	50.32	37.60	25%
0201	Andrychów Forest District	21.66%	49.04	47.52	3%
0205	Gidle Forest District	20.36%	42.69	42.38	1%
0226	Rybnik Forest District	20.18%	41.03	39.59	4%
0223	Prószków Forest District	19.99%	42.45	39.01	8%
0213	Kobiór Forest District	17.50%	36.62	32.31	12%
MODERATELY HIGH RISK					
No.	**Entity name**	**% of average annual timber sales revenue**	**maximum change in total average timber sale price (in PLN)**	**maximum change in total average timber sale price after eliminating quantitative factor (in PLN)**	**impact of change in weight of timber sold over considered period**
0225	Rudziniec Forest District	14.12%	28.09	11.87	58%
0227	Siewierz Forest District	14.04%	24.98	23.46	6%
0236	Węgierska Górka Forest District	11.12%	28.58	24.50	14%
0224	Rudy Raciborskie Forest District	11.11%	21.34	18.76	12%
0228	Strzelce Opolskie Forest District	10.96%	21.73	20.35	6%
0235	Wisła Forest District	10.53%	22.12	21.20	4%
MODERATE RISK					
No.	**Entity name**	**% of average annual timber sales revenue**	**maximum change in total average timber sale price (in PLN)**	**maximum change in total average timber sale price after eliminating quantitative factor (in PLN)**	**impact of change in weight of timber sold over considered period**
0218	Lubliniec Forest District	9.62%	19.12	17.16	10%
0238	Opole Forest District	9.41%	18.73	16.72	11%

0211	Kluczbork Forest District	9.24%	21.11	21.03	0%
0204	Brzeg Forest District	9.12%	18.55	18.09	2%
0229	Sucha Forest District	9.10%	20.35	18.55	9%
0237	Złoty Potok Forest District	8.35%	15.98	14.12	12%
0231	Turawa Forest District	8.21%	17.44	16.94	3%
0221	Olkusz Forest District	8.06%	14.05	13.54	4%
0233	Ujsoły Forest District	7.68%	20.31	19.29	5%
0210	Kędzierzyn Forest District	7.68%	13.50	12.89	5%
0212	Kłobuck Forest District	7.37%	16.12	15.85	2%
0214	Zawadzkie Forest District	7.32%	14.77	14.35	3%
0222	Prudnik Forest District	7.28%	15.80	10.71	32%
0208	Jeleśnia Forest District	7.10%	16.35	15.33	6%
0232	Tułowice Forest District	7.07%	14.67	12.42	15%
0207	Chrzanów Forest District	6.80%	12.51	11.39	9%
0215	Koniecpol Forest District	6.72%	13.70	12.93	6%
0219	Namysłów Forest District	6.49%	12.82	12.62	2%
0220	Olesno Forest District	5.94%	12.90	12.56	3%
0234	Ustroń Forest District	5.57%	12.85	11.29	12%
0217	Kup Forest District	5.20%	10.31	10.06	2%

LOW RISK

No.	Entity name	% of average annual timber sales revenue	maximum change in total average timber sale price (in PLN)	maximum change in total average timber sale price after eliminating quantitative factor (in PLN)	impact of change in weight of timber sold over considered period
0230	Świerklaniec Forest District	4.58%	8.52	8.21	4%
0203	Brynek Forest District	4.08%	7.42	6.74	9%
0202	Bielsko Forest District	3.91%	8.32	7.89	5%
0216	Koszęcin Forest District	3.65%	7.21	6.99	3%
0209	Katowice Forest District	2.84%	4.98	4.81	4%

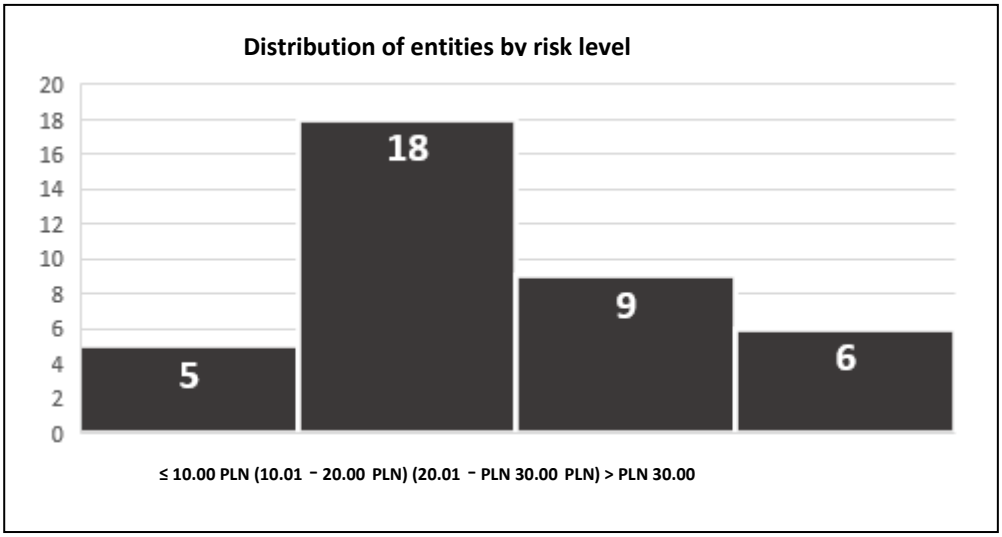

Fig. 2. Distribution of entities of Katowice Regional Directorate of State Forests by risk level

In the next section of this paper, attention is drawn to estimating the values at risk bearing in mind the criterion of groups according to the qualitative and dimensional classification of timber. In view of the sales prices of the different assortments resulting from their quality, potential for use in the timber industry, as well as the demand itself, it was found that the sales of large-sized logs had a higher TSPR than medium-sized logs, including large-diameter coniferous timber, for which the level of risk was the highest. This was due to the volume of sales, which reached the highest values for large-diameter coniferous timber. Similarly, in the case of medium-sized logs, a relationship was observed between TSPR and the sales volume (Table 4).

Table 4. Analysis of value at risk for individual timber sales groups

		Large-diameter deciduous timber		Large-diameter coniferous timber		S2A deciduous		S2A coniferous	
No.	**Entity name**	**VaR annual (in millions PLN)**	**% of revenue from sales of large-diameter deciduous timber**	**VaR annual (in millions PLN)**	**% of revenue from sales of large-diameter coniferous timber**	**VaR annual (in millions PLN)**	**% of revenue from sales of S2A deciduous timber**	**VaR annual (in millions PLN)**	**% of revenue from sales of S2A coniferous timber**
0201	Andrychów Forest District	1.78	12%	0.24	1.64%	0.15	1.05%	0.07	0.48%
0202	Bielsko Forest District	0.39	3%	0.70	6.11%	0.18	1.54%	0.13	1.13%
0203	Brynek Forest District	0.24	2%	0.41	3.62%	0.05	0.42%	0.25	2.25%
0204	Brzeg Forest District	1.47	8%	0.77	4.25%	0.34	1.89%	0.41	2.25%
0205	Gidle Forest District	0.77	4%	4.30	23.58%	0.18	1.00%	0.49	2.71%
0206	Herby Forest District	0.69	6%	1.50	11.98%	0.15	1.19%	0.18	1.45%

0207	Chrzanów Forest District	0.23	2%	1.06	8.10%	0.22	1.65%	0.31	2.39%
0208	Jeleśnia Forest District	0.31	2%	0.96	5.02%	0.12	0.64%	0.23	1.20%
0209	Katowice Forest District	0.26	3%	0.26	3.29%	0.10	1.30%	0.13	1.67%
0210	Kędzierzyn Forest District	0.49	5%	0.41	3.88%	0.23	2.19%	0.26	2.47%
0211	Kluczbork Forest District	0.81	4%	1.39	6.26%	0.01	0.04%	0.55	2.46%
0212	Kłobuck Forest District	0.53	3%	0.75	4.21%	0.09	0.48%	0.20	1.14%
0213	Kobiór Forest District	0.54	2%	4.40	19.23%	0.16	0.69%	0.21	0.92%
0214	Zawadzkie Forest District	0.19	1%	1.16	6.35%	0.09	0.50%	0.42	2.31%
0215	Koniecpol Forest District	0.56	3%	0.53	3.27%	0.06	0.36%	0.11	0.66%
0216	Koszęcin Forest District	0.25	1%	0.64	3.74%	0.09	0.55%	0.20	1.19%
0217	Kup Forest District	0.36	2%	0.92	4.44%	0.13	0.62%	0.43	2.08%
0218	Lubliniec Forest District	0.59	3%	1.71	7.74%	0.13	0.58%	0.28	1.26%
0219	Namysłów Forest District	0.69	4%	1.08	5.53%	0.12	0.59%	0.76	3.87%
0220	Olesno Forest District	0.69	3%	0.20	0.97%	0.14	0.68%	0.56	2.74%
0221	Olkusz Forest District	0.32	3%	0.63	5.53%	0.11	0.95%	0.24	2.12%
0222	Prudnik Forest District	1.58	6%	1.35	5.04%	0.11	0.41%	0.43	1.59%
0223	Prószków Forest District	1.33	6%	3.42	14.51%	0.08	0.35%	0.42	1.78%
0224	Rudy Raciborskie Forest District	0.62	4%	1.07	6.28%	0.21	1.25%	0.38	2.26%
0225	Rudziniec Forest District	1.67	7%	3.12	13.71%	0.10	0.42%	0.60	2.62%
0226	Rybnik Forest District	1.63	8%	2.32	11.77%	0.26	1.33%	0.29	1.50%
0227	Siewierz Forest District	1.09	11%	0.40	4.14%	0.23	2.42%	0.13	1.41%
0228	Strzelce Opolskie Forest District	0.89	4%	1.28	6.43%	0.26	1.33%	0.62	3.14%
0229	Sucha Forest District	1.08	8%	0.53	4.07%	0.04	0.28%	0.16	1.23%
0230	Świerklaniec Forest District	0.24	1%	0.59	3.64%	0.11	0.70%	0.31	1.90%
0231	Turawa Forest District	0.77	3%	1.29	5.25%	0.17	0.69%	0.28	1.14%

0232	Tułowice Forest District	0.46	2%	0.80	3.88%	0.15	0.72%	0.53	2.56%
0233	Ujsoły Forest District	0.18	0%	3.39	6.86%	0.02	0.04%	2.93	5.92%
0234	Ustroń Forest District	0.37	2%	1.20	6.64%	0.01	0.08%	0.14	0.77%
0235	Wisła Forest District	0.10	2%	0.71	11.69%	0.04	0.62%	0.12	1.96%
0236	Węgierska Górka Forest District	0.04	0%	2.42	11.57%	0.01	0.03%	0.26	1.25%
0237	Złoty Potok Forest District	0.38	3%	0.77	5.50%	0.20	1.41%	0.15	1.08%
0238	Opole Forest District	0.95	3%	1.97	6.94%	0.15	0.52%	0.75	2.66%

Conclusions

1. The concept of timber selling price risk (TSPR) estimation presented in this article demonstrates that the application of the VaR method can be an auxiliary tool in the process of TSPR management.
2. Introducing the assumptions of the VaR method into the estimation of TSPR can provide a basic tool to quantify and assess the scale of risk while taking into account the significant impact of the effect of sales volume and the structure of commercial classes of timber on TSPR.
3. Using the approach presented in the article, a significant relationship between the level of generated revenue and TSPR, as well as the assortment structure and TSPR, was identified and discussed.
4. Based on the obtained results, a significant effect of the structure of timber classes on TSPR was found for the analysed population.
5. The review of the literature confirms that the proposed concept of TSPR quantification is an innovative approach to estimate market risk in the field of forest management in Poland and is a solid basis for its further improvement.
6. Based on the results of the conducted research, the authors indicate the existence of such factors as: the variability of the number of cuts in the examined time horizons and the inability to take into account other risks in the examined model as factors limiting the possibility of its application.
7. On the basis of the accumulated knowledge, it should be indicated that the further direction of research in order to develop the proposed research path should be to extend the time horizons of VaR prediction, e.g. from years to months or weeks, in order to obtain more accurate research results.

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APPENDIX 1: Statistical data

Entity No	Entity name	Sales value in PLN millions. 2015	Sales value in PLN millions . 2016	Sales value in PLN millions. 2017	Sales value in PLN millions. 2018	Annual VAR as the amount of revenues from the sale of wood in 2015 in PLN million	Annual VAR as the amount of revenue s from the sale of wood in 2016 in PLN million	Annual VAR as the amount of revenues from the sale of wood in 2017 in PLN million	Annual VAR as the amount of revenues from the sale of wood in 2018 in PLN million	Quantity of wood sold in 2015 in M3	Quantity of wood sold in 2016 in M3	Quantity of wood sold in 2017 in M3	Quantity of wood sold in 2018 in M3
0201	Nadleśnictwo Andrychów	12.51	13.82	15.93	15.64	2.62	2.90	3.34	3.28	61 148.00	60 547.00	66 782.00	66 725.00
0202	Nadleśnictwo Bielsko	12.58	11.76	11.50	10.25	0.47	0.44	0.43	0.38	58 688.00	56 324.00	53 497.00	48 129.00
0203	Nadleśnictwo Brynek	10.62	13.14	10.05	11.24	0.39	0.49	0.37	0.42	58 337.00	73 837.00	54 413.00	61 508.00
0204	Nadleśnictwo Brzeg	17.57	18.61	19.39	17.44	1.56	1.65	1.72	1.55	86 664.00	90 086.00	92 665.00	89 412.00
0205	Nadleśnictwo Gidle	16.96	17.22	19.41	19.41	3.43	3.48	3.92	3.92	85 840.00	87 328.00	87 327.00	87 543.00
0206	Nadleśnictwo Herby	7.33	6.48	17.06	19.32	1.36	1.20	3.16	3.57	37 986.00	35 238.00	77 372.00	89 595.00
0207	Nadleśnictwo Chrzanów	11.85	12.93	12.37	15.00	0.73	0.80	0.77	0.93	63 573.00	72 223.00	65 400.00	82 724.00
0208	Nadleśnictwo Jeleśnia	17.96	18.06	21.32	18.82	1.20	1.20	1.42	1.25	78 818.00	80 378.00	91 556.00	79 931.00
0209	Nadleśnictwo Katowice	8.36	7.89	7.33	8.61	0.23	0.22	0.20	0.24	47 730.00	45 679.00	41 577.00	48 514.00
0210	Nadleśnictwo Kędzierzyn	10.21	10.58	9.97	11.62	0.75	0.78	0.73	0.85	56 585.00	62 789.00	56 513.00	65 302.00
0211	Nadleśnictwo Kluczbork	21.27	22.20	22.52	22.63	1.96	2.04	2.07	2.08	96 914.00	96 685.00	96 567.00	97 496.00
0212	Nadleśnictwo Kłobuck	17.52	18.25	17.95	17.86	1.27	1.32	1.30	1.29	82 614.00	83 716.00	80 435.00	80 443.00
0213	Nadleśnictwo Kobiór	25.28	24.66	21.61	20.03	3.90	3.81	3.34	3.09	112 743.00	125 802.00	101 677.00	98 179.00

0214	Nadleśnictwo Zawadzkie	17.70	18.63	18.15	18.68	1.26	1.33	1.29	1.33	88 807.00	94 841.00	89 357.00	89 844.00
0215	Nadleśnictwo Koniecpol	14.27	16.56	17.01	17.37	0.91	1.05	1.08	1.10	71 937.00	81 742.00	82 996.00	82 977.00
0216	Nadleśnictwo Koszęcin	16.95	17.47	17.42	16.25	0.60	0.62	0.62	0.58	86 930.00	88 991.00	86 647.00	82 448.00
0217	Nadleśnictwo Kup	20.03	20.34	21.62	21.38	1.02	1.03	1.10	1.08	102 283.00	104 282.00	106 578.00	107 153.00
0218	Nadleśnictwo Lubliniec	19.20	24.33	22.10	23.03	1.66	2.10	1.91	1.99	96 206.00	117 291.00	115 111.00	117 140.00
0219	Nadleśnictwo Namysłów	19.51	18.74	19.83	20.32	1.25	1.20	1.27	1.30	98 733.00	97 982.00	98 780.00	101 374.00
0220	Nadleśnictwo Olesno	20.07	20.32	20.14	20.93	1.16	1.18	1.17	1.21	93 686.00	94 989.00	90 447.00	96 178.00
0221	Nadleśnictwo Olkusz	10.90	10.90	12.50	10.99	0.85	0.85	0.97	0.85	62 637.00	65 356.00	69 866.00	61 902.00
0222	Nadleśnictwo Prudnik	28.28	34.24	24.81	19.85	1.40	1.69	1.22	0.98	132 108.00	161 648.00	113 237.00	89 075.00
0223	Nadleśnictwo Prószków	23.38	24.09	21.60	25.28	4.30	4.43	3.97	4.65	110 676.00	122 972.00	101 755.00	109 972.00
0224	Nadleśnictwo Rudy Raciborskie	12.94	17.08	18.40	19.60	1.26	1.67	1.80	1.91	70 763.00	90 277.00	92 646.00	99 123.00
0225	Nadleśnictwo Rudziniec	10.10	15.67	33.64	31.62	0.60	0.94	2.01	1.89	51 789.00	78 617.00	158 683.00	166 921.00
0226	Nadleśnictwo Rybnik	18.20	18.24	20.29	22.00	3.55	3.55	3.95	4.29	91 156.00	97 534.00	98 744.00	99 615.00
0227	Nadleśnictwo Siewierz	9.96	10.21	8.79	9.30	1.31	1.35	1.16	1.23	58 153.00	60 092.00	46 167.00	51 616.00
0228	Nadleśnictwo Strzelce Opolskie	19.17	17.67	20.53	22.08	1.97	1.81	2.11	2.27	97 994.00	93 455.00	99 985.00	108 704.00
0229	Nadleśnictwo Sucha	11.05	11.25	14.87	15.33	0.92	0.93	1.23	1.27	50 172.00	51 935.00	65 271.00	66 788.00
0230	Nadleśnictwo Świerklaniec	15.28	16.58	17.07	16.20	0.67	0.73	0.75	0.71	82 914.00	90 353.00	89 590.00	86 911.00
0231	Nadleśnictwo Turawa	23.41	23.75	25.89	24.95	1.87	1.89	2.07	1.99	112 371.00	114 867.00	119 169.00	114 990.00
0232	Nadleśnictwo Tułowice	17.07	18.07	23.03	24.09	1.02	1.08	1.38	1.44	83 757.00	88 941.00	108 547.00	113 955.00
0233	Nadleśnictwo Ujsoły	49.86	49.56	50.89	47.45	3.64	3.62	3.71	3.46	191 377.00	189 409.00	186 981.00	180 374.00
0234	Nadleśnictwo Ustroń	19.55	18.96	19.61	14.43	0.96	0.93	0.96	0.71	84 328.00	84 318.00	84 315.00	61 857.00
0235	Nadleśnictwo Wisła	4.94	5.57	7.22	6.73	0.50	0.56	0.73	0.68	24 678.00	26 620.00	33 768.00	31 068.00

0236	Nadleśnictwo Węgierska Górka	23.74	23.99	20.86	15.10	2.26	2.29	1.99	1.44	89 637.00	92 752.00	80 903.00	61 217.00
0237	Nadleśnictwo Złoty Potok	11.67	12.03	16.66	15.71	0.86	0.89	1.23	1.16	61 416.00	65 319.00	84 983.00	80 287.00
0238	Nadleśnictwo Opole	25.79	27.98	27.58	32.21	2.17	2.35	2.32	2.71	135 452.00	141 319.00	135 491.00	157 946.00