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The Forest Market – Income Methods for Determining the Value of Forest Resources

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Abstract. This article describes the methods for estimating the value of a forest, the accuracy of which is critical for purchases and sales, credit security, determining the shares in the division of forest real estate, as well as in determining the amount of compensation for losses in forest property. Compensation for property losses also includes past events that occurred before the Second World War, such as nationalization or loss of the forests in the eastern territories of the Second Polish Republic due to border changes. An equally important objective of forest valuation, which has recently gained in importance, is the inclusion of its value in a forest holding balance sheet. However, due to the lack of fully objective market prices for forest property, this work focused on the analysis of the quantitative and qualitative characteristics of the forest market and the methods of calculating the income (rent) value of the forest. Examples of commercial transactions from the forest market in the USA, Austria and Germany are included.

The study presents a historical outline of forest valuation with particular emphasis on methods based on the income value, including forest rents. Furthermore, we discuss the formula of the perpetual capitalization of annuity and periodic annuity, including the impact of various net income calculations, that is, in arrears or in advance

Keywords: and price of a forest, forest market, forest rent, methods of the capitalization of forest income

1. Introduction

Forest management became subject to free market mechanisms over 150 years ago, generating a radical increase in private forest ownership as a result of the sale of state forests and the affranchissement of peasants. This required the income from a forest and its value to be determined, among others, to assess the profitability of investing capital in forest assets. Within a short period of time, this had fatal consequences for the forest. Virtually unrestricted, forest management methods led to the far-reaching devastation of forests together with a decrease in their area in many European countries. Forestry was simply unable to compete for capital with other opportunities for investment due to the low profitability of forest management. In order to prevent further destruction of forests, the governments of some countries began to buy forests from private owners at the end of the second half of the 19th century, and at the same time, the first laws on forests introducing the practice of the principle of forest sustainability were enacted (Klocek 2006). Its strengthening in subsequent acts had a significant impact on limiting the free market-based trade of forests. The resulting lack of adequate forest prices forced a search for non-market methods to assess its value. The scope of these methods concerned either the entire forest as an indivisible economic unit, or only the forest land or tree stand. Each of these factors in forest management could be the subject of a separate market transaction and the basis for a separate calculation of its value.

As time passed, new functions of forest assets appeared and new reasons for assessing their value have emerged (Gartzke et al. 2007; Institut für Agrar...). Knowing the value of the forest was indispensable for various activities, such as trade (sale-purchase), assessing damages (establishing compensation), securing loans, determining the shares of property distribution, converting usage rights (e.g., conversion of easements to ownership rights), taxation, or inclusion of forest value changes in the economic balance sheet of a forest holding. The last of these cases is of great importance

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in countries where the valuation of state forests is mandatory (including Poland), often associated with its inclusion in the balance sheet of the forest holding (Zając, Świętojański 2002; Klocek, Płotkowski 2009).

2. The market value of the forest

2.1. The dearth of market prices for forests

In a market economy, the monetary expression of the objective value of various goods (commodities) is their price, which is shaped by the relationship between their demand and supply. Unfortunately, due to the short period in which a full market economy has been functioning in Poland, and at the same time, the negligible share of forests in the turnover of material goods and, finally, the low interest in the forest market by the economy of forest management, systematic theoretical and practical knowledge in the field of the market prices of forests is lacking. Therefore, it is worth referring to the scientific achievements, experiences and solutions used in this area from other countries, to visualize and draw appropriate conclusions as to the requirements for market information when determining the value of a forest. Ostensibly, it seems that in the first place, one should refer to data on the forest market in the USA, where there are extensive analyses and cover over a 100 year period. Suffice it to say that in 2008 alone, the value of investment turnover in the US forest market was $50 billion (Bockum 2009). However, in view of the considerable freedom of an owner to dispose of his/her own forest in the broad sense of the term, the US market is fundamentally different than the conditions in Europe, where forest law imposes many restrictions, both in the choice of forest management methods and in forest protection.

Among the European countries, Germany has particularly rich theoretical and practical achievements in the areas under discussion. After unification, it began to denationalize forests in the five eastern federal states (länder). The relevant legal regulations issued for this purpose led to the sale of 526,000 ha of forests between January 1, 1995 and June 30, 2008, with the most sold in Brandenburg – 200,000 ha, the least in Thuringia – just over 50,000 ha, and about 90,000 ha in the other three states (Loboda 2008). It was extremely important to strive to comply with the legal and economic requirements regarding the general principles of the market of material goods. This was reflected in periodic publications, including in 2000, both the federal and state 'Guidelines on Determining the Value of the Forest' (WaldR, 2000), which define the market (commercial) value of the forest generally as 'the price that would be achieved on the date when the value of the forest is established under normal commercial conditions, in accordance with the legal framework and reliable data on the status and location of the forest, regardless of extraordinary and personal relationships to the "purchase and sale" act' (Moog 1994; Schmid 2004; Schuster 1992).

It should be emphasized that the forest market in virtually every European country does not meet all the conditions and requirements resulting from the above definition in practice. It is worth discussing them at least briefly to explain why the use of market prices to determine the value of a forest raises much criticism and ongoing discussion, consequently leading to discrepancies between the price and its value (Bundesrat 2008). The starting point for the analysis of these phenomena are the quantitative and qualitative characteristics of the so-called perfect market, which are presented as follows (Löffler, 2005; Moog, 1994):

1. **The homogeneity and substitutability of the forest as a market good**. In terms of the degree of homogeneity (equivalence), the forest fundamentally differs from other market goods. This is conditioned by the permanence (immutability) of its location, which makes a given forest for a specific buyer 'one of a kind', if only due to its proximity to the buyer's place of residence and the resulting benefits to him of this. Another reason for this phenomenon is the diversity of the species composition of the tree stands, or the richness of forest fauna. It is already clear from these examples that the low degree of homogeneity results in low substitutability in the forest market. Thus, for a buyer, a given forest cannot be replaced by another, not only due to material reasons, but also because of the non-material ones that cannot be quantified. Non-material considerations also affect the supply of the forest. This is confirmed by the opinion that an owner of a forest inherited from the previous generations (ancestors) is not willing to sell it, despite being offered a high price and the opportunity to buy another forest.

2. **The spatial and temporal diversification of the forest market.** Another reason for the imperfection of the forest market is the spatial diversification of its supply and demand. At the root of this phenomenon is unequal forest cover and differing shares of private forest ownership in individual regions of the country. This is clearly evidenced by the situation in Germany, where the eastern länder have a supply that significantly exceeds the demand for forests.

As a result, forest prices are lower there than in the western länder, despite the introduction of preferential sales prices by the national government (Bundesrat 2008; Gerold 1999). On the other hand, the forest market is the opposite of markets with a low supply intensity over time. The forest is not subject to physical deterioration in the short term, nor to the so-called economic depreciation, as is the case with many other goods requiring quick sales. For this reason also, forests are not subject to the time-based coordination of supply and demand.

3. **The availability and completeness of information about the forest market.** The forest market is substantially different in this respect from the market of other goods, including real estate. Only in the case of the sale of large areas of forest is relevant information available to a wider range of in-

terested buyers. However, for smaller parcels, this information is only locally accessible. There is virtually no comparison with goods that are traded on stock exchanges. Naturally, this does not apply to wood, whose prices undoubtedly have an impact on forest prices.

4. **Extraordinary and personal business relationships (preferences).** In order to clarify the essence of this issue, it is worth quoting a ruling of the Austrian Administrative Court, which stated that 'ordinary commercial relations (trade) should be understood as trade operating in accordance with the market rules of supply and demand, with each participant acting without coercion or pressure or special reasons, but voluntarily and in accordance with his/her own interests' (Moog 1994). If these conditions are not met, then the price of the forest does not determine its value, because: a) it deviates from the prices of identical (homogeneous) forests, b) it was negotiated under the extraordinary interests of the seller or buyer, c) there are special relations of kinship or economic ties between the seller and the buyer, d) the income and management costs significantly differ from those for other similar forests.

These factors mean that the market value of the forest is not 'the value for everyone' (Gerold 1999) or, in another context, the commercial value is not equal to the public value in material terms (Moog, 1994). In other words, the price of the forest in such a case differs from its universal value, which would be determined in an ideal market, called the perfect market in economics (Bundesrat, 2008), balancing the supply and demand for the forest. Achieving parity in these economic categories, in accordance with the abovementioned definition of the forest market, requires the elimination of 'extraordinary and personal relationships between the parties of the sale and purchase agreement' and an adjustment of the price achieved on this basis. However, this is extremely difficult, especially when the forest market is very limited and the reasons listed for its deviation from the premises of a perfect market are so universal.

One of these reasons is the physical proximity of a sold forest to the forest of a potential buyer, who intends to increase his forest assets. In this case, he will treat the possible purchase transaction as an 'extraordinary opportunity' and will be prepared to even pay an inflated price.

A completely opposite phenomenon occurs when a forest is sold under the influence of sentimental attitudes towards family relationships. The view that 'the forest should remain in the family' leads to favouring relatives, and as a result, a willingness to sell the forest at a lower price than a non-family buyer would pay. This is confirmed by many market transactions, including those of forest sales to 'close neighbours' (Löffler 2005).

The literature on this subject also includes the indirect impact of forest market transaction costs in the category of extraordinary and personal relationships. They are the result of restrictive regulations on land trade, which require securing approval for such transactions (Moog, 1994). In Poland, this has already been reflected in the constitutions of the Republic of Poland of March 17, 1921 and of April 23, 1935, which state, among others, 'The land, as one of the most important factors constituting the existence of the nation and the State, cannot be the object of unlimited trade.' Limitations on land trade in Poland were introduced by the Act of 13 April 2016 amending the Act on Forests (Article 37a, paragraph 1), which states 'in the case of the sale of ... land by a natural person, a legal person or an organizational unit without legal personage, the State Treasury, represented by the State Forests National Forest Holding has the pre-emptive right to purchase this land' (Journal of Laws of 2017, item 788). Limitations on land trade also takes place in other countries. It was introduced in Germany by the Act of 1961 on actions to improve the structure of the forest and the security of agricultural farms and forest plantations (Klocek 2000). In addition to these restrictions, large expenditures are incurred for geodetic valuation and measurement, inventorying, land acquisition tax and so on. On the other hand, many investors prefer to invest their free capital in agricultural and forest real estate for tax purposes. This applies, for example, to capital obtained through inheritance and making such investments to lower inheritance taxes (Bundesrat 2008).

2.2. Characteristics of the transactions in the forest market

To supplement these considerations of the forest market, it is worth quoting some figures. The most significant in this respect is the small share of annual forest transactions given the total forest area. For Lower Saxony in 1985–1998, it was on average from 1.2 to 3.5 per thousand per year. In Austria, on the other hand, the average annual transactions in the years 1981–1998 fluctuated, depending on the region, between 1.1 and 1.5 per thousand. The author of the quoted data puts forward the thesis that based on these data, there is no forest market (Löffler, 2005). A completely different situation exists in the five eastern German länder. In accordance with the reprivatisation program adopted after the unification of this country, the share of private forests in eastern Germany is expected to reach 50% (1,568,000 ha) and will range from 38% (191,000 ha) in Mecklenburg-Vorpommern to 60% (656,000 ha) in Brandenburg (Spinner 2002). The sale of such large areas of forest is episodic, and after its completion, the forest market will return to a situation characterized by a negligible share of 'purchase and sale' transactions.

Confirmation of both the lack of homogeneity in the forest market and the significant role of personal preferences are the diverse motives for purchasing a forest. According to the data for eastern Germany, these motives, rated on a five-point scale (from 1 – no significance, up to 5 – very significant), were as follows in 2001 (Spinner 2002):

- tax benefits 1.55
- capital investment 2.24
- personal recreational use 3.05
- income from the sale of wood 3.12
- supply of one's own wood 3.41
- nature conservation 3.45
- ideological values 3.76

The survey above was conducted among 1090 forest buyers, who by 2001 had purchased a total of 239,000 ha of forest. Of these buyers, 57% bought forest plots of up to 10 ha, 18% – from 10 to 75 ha, and only 7% purchased forests with an area of over 500 ha each. The main group of forest buyers (46%) were owners of agricultural farms, but only 7% of them secured their income only from agricultural farming. On the other hand, the share of buyers whose main source of income was forest management was 13%.

From the above-mentioned data, the high rating of forest purchases for nature conservation (3.45) and for ideological reasons (3.76), which includes pride in owning a forest and family tradition, deserves special attention. These reasons were cited above all by the former forest owners. It is worth noting the fact that the highest demand in terms of the number of purchasers was for small forest areas, which, as can be expected, should obtain the highest prices. This is indeed confirmed by 1995 data on the average price of agricultural and forest land purchased in Austria (Löffler 2005). They show, among others, that the average price for 0.5 to 1.0 ha was 2.69 €/m^2, 2.33 €/m^2 for 1.0 to 5.0 ha and only 2.25 €/m^2 for 5.0 to 10.0 ha of land.

Much greater differences in forest purchase prices took place in the new German länder. At the end of 1990s, the price of a pine forest ranged from 800 to 1200 DM/ha, and averaged 1000 DM/ha. The price of a spruce forest was respectively: 1300–3000, and averaged 2400 DM/ha, while hardwood forests cost 1300–3000, averaging 1700 DM/ha (Gerold 1999). However, the average preferential forest prices introduced by the German government in 2001 were much higher. They were mainly targeted to former owners and buyers offering better forest management programs that had the funds for their implementation. These prices ranged from 765 €/ha (Brandenburg) to 1312 €/ha (Thuringia), while their average was 911 €/ha (Wötzel 2002). In the following years, forest prices continued to grow slowly, and in 2007, reached an average of 1166 €/ha: 764 €/ha in Saxony, 970 €/ha Brandenburg, 1156 €/ha in Mecklenburg-Vorpommern, 1104 €/ha in Saxony-Anhalt and 1838 €/ha in Thuringia (Loboda 2008). Of course, the so-called free market prices were higher, however, the share of such sales in the total forest turnover was only just over 20% (Wötzel 2002), and therefore, did not determine the turnover in the forest market. The dominant role was played by Assessment and Land Management LLC (BVVG), a company specially established for forest sales, acting on behalf of the Ministry of Finance. Its position on the forest market has led to a situation assessed as a bilateral (two-sided) monopoly (Löffler 2005). Its characteristic feature is obtaining a price ensuring only one party with income, while the other party has to settle for no income. The first of these parties is the aforementioned company, which, using its concessional authority, led to price imbalances and very high profits, resulting in the fear of new forest owners about their future income from forest management due to the discrepancy between the income value of the forest and its market purchase price (Institut ... 2002; Moog 1994).

Given the above characteristics, one has to agree with the opinion that under the conditions of an imperfect market, we are dealing with inadequate forest prices due to the difficulty of excluding all the circumstances and relations that are inappropriate for the market (Moog 1994). In other words, values appearing in such a market are not the 'values for everyone', but only for those who are guided by special preferences (Gerold 1999). In turn, the eminent expert on this issue, Brabänder, sees the main cause of the shortcomings of the forest market in the absence of homogeneity (Brabänder, Finckenstein 1993). The synthesis of these critical opinions is the statement: 'the conditions of a perfect market are fulfilled to such a small degree by the forest market that it is doubtful that one can even talk about such a market' (Löffler 2005) or simply: 'practically, no forest market exists' (Gerold 1999).

Federal and länder guidelines for determining the value of the forest (WaldR 2000), which were amended several times, were also criticized. This criticism, in fact, affected not so much the legal order to reprivatize the forests in Germany's eastern länder, but its valuation for the sales (Brabänder, Finckenstein 1993). Here, in turn, the focus of criticism was directed at the unjustified, in terms of its substance and methodology, separation of estimating the value of the land and the value of the tree stand.

The first of these is determined on the basis of price quotations for forest land sales prices, but also takes into account the prices of agricultural land (Schuster 1992). It is worth adding that according to experts, market prices for forest land amount to about 30–40% of the value of agricultural land, while the ratio of land value to the value of the tree stand on the land changed from 1 to 2–3 to the current 1 to 1 (Gerold 1999). Referencing the price of forest land to the price of agricultural land when determining its value is criticized because revenue methods are used to assess agricultural land values, which invariably leads to overestimating forest land prices. Meanwhile, tree stands as a source of income from forested land are managed with a view towards their future financial gains to a much smaller degree (Moog 1994), thus making land in forests much less profitable than agricultural land.

On the other hand, the value of the tree stands in the discussed guidelines is estimated depending on their age on the basis of market categories, either by the cost method (for young stands) or the expected harvested value (stands of average age classes) or the harvested/saleable value (stands almost ready to be harvested and harvestable stands). Adding these values, which are determined in such varied ways, is erroneous, which is best evidenced by the completely different results of calculating the value of the same tree stand using the method of incurred costs and the expected harvest value (Moog 2007).

However, the focus of the criticism is most strongly directed towards separating the estimated value of forest land and the value of the tree stand, which is substantively incorrect, and even impossible and artificial (Gerold 1999). The holistic unity of these two factors results not only from the long-term cycle of forest production, which is not analogous to agriculture, but above all, from the principle of forest sustainability, which radically limits the possibilities of changing the land use category of a forest. Thus, there are practically no alternative ways of using forest land.

3. Income value (profitability) of the forest

3.1. The history of forest valuation using the income approach

Many forest economists, including Brabänder and Finckenstein (1993), believe that when valuing a forest, priority should be given to the income approach, as both the forest seller and buyer are oriented towards the future in their decision. They are primarily interested in future financial streams in the form of incoming payments (revenues) and expenses (outlays) relating to forest ownership and its business activities. The net income calculated on this basis makes it possible to determine the value of the capital worth investing in forest management to obtain the expected profit (effectiveness) from the investment. The higher the expectations regarding profitability, the smaller the value of the forest at a given net income. However, the higher the net income, the higher the value of the forest at a given level of profitability of forest management. The dependence of the value of the forest on the individual expectations of a buyer and seller indicates a certain subjectivity in assessing its value. This applies not only to the market prices of the forest, but also to the methods based on the expected income value of the forest (Gartzke et al. 2007).

The mathematical bases of the methods for determining the income value of the forest were developed by Faustmann (1849), who referenced them primarily to the valuation of forest land. It is worth mentioning that these bases were already developed in Germany, and their precursor was Johann Hossfeld – a mathematician who in 1805 presented the concept of calculating the derivative of the value of the forest (Vittala 2016). Nevertheless, it was the development of Faustmann's methods of determining income value that became the basis of forest statistics, as a new discipline of forest science and the modern direction of the development of forest management together with its positive and negative effects. Their qualities were highly valued by the United States Nobel Prize winner in economics, Paul A. Samuelson, who wrote that Faustmann laid the foundation for modern investment account methods (Boungiorno 2001). Currently, they are widely used to assess the value of enterprises, while their mathematical aspects have found a worthy place in numerous publications devoted to financial mathematics (Podgórska, Klimkowska 2005).

The discussed methods of estimating the income value of the forest also dominated in Poland's forestry after regaining its independence after the first world war. This was reflected both in the professional literature (Jedliński 1947), as well as in the forest policy of the state and the practice of forestry. One of the first manifestations of the use of these methods was the valuation of the forests taken over by the government under the Treaty of Versailles of 1919 and resulting from this, damages. As Studniarski stressed (1928), using the income approach to assess the forests' value includes the value of all elements of forest management, and therefore, requiring the Prussian government to pay separate compensation for forest buildings was unsubstantiated.

The next reference to the income approach of forest valuation relates to the Sejm Resolution of 10 July 1919 and the Act of 15 July 1920 on agrarian reform (Bielański 1921), which postulated 'the nationalization of forests in return for compensation' (Ruśkiewicz 1931a). The amount of this compensation was to be calculated 'according to the capitalized net income from state forests' (Bielański 1921). The compulsory buy-back by the state of private forests, which were included in the agricultural property covered by such a solution, was repealed by the Act of 28 December 1925 on agrarian reform, which determined that forests with an area of over 30 ha, and in north-eastern areas over 50 ha, were not subject to parcelling. However, this did not stop private forests from passing from private to state ownership, but this could occur only through voluntary sales. This was favoured by the minimal profits from private forest management, in other words – the very low interest rate on capital represented by only the tree stands (Ruśkiewicz 1932a). For this same reason, there was devastating forest exploitation and even the free transfer of private forests to the state of several hundred or more hectares in exchange for permission to harvest the tree stand from age class V and higher in the transferred forest (Ruśkiewicz 1932b). Of course, such solutions were not accepted by the state due to the principles in force of sustainability and the continuity of forest use in forest management. The aforementioned situation fostered forest owners' support of state purchases of forests based on the valuation of its commercial value, understood as 'the capitalization

of net annual income, because Polish law allows only limited forest exploitation' (Ruśkiewicz 1932b).

In principle, all subsequent regulations and studies on determining the value of the forest referred to the capitalization of net income from forest management. It was used, among others, with reference to the regulations on the taxation of land for the Towarzystwo Kredytowe Ziemskiego [Association of Land Credit] in Warsaw from 1935 (Regulations... 1935). Paragraph 43 thereof provides that the value of forests 'is estimated on the basis of calculating the expected revenues in particular periods, obtained from the difference between income and expected expenses. The calculated expected revenues and expenses are discounted at the present time, and the net income is capitalized at an interest rate of 3'. The discounting mentioned in these provisions indicates that they also pertained to forests providing periodic income, and not only annual income, as in the case of a normal forest. A more tolerant approach was adopted by the Poznań Land Credit Association, according to which 'the net annual income is averaged over a 10-year period, the so-called forest income, capitalized by 33 (this should be 3.3 – AK and SZ) and the income value of the forest is obtained' (Newelski 1936).

The capitalization method was also used to determine the value of forest parcels expropriated under Art. 3 of the PKWN Decree of December 12, 1944 on taking possession of certain forests for state ownership (Journal of Laws of the Republic of Poland, No. 15, item 82). The Regulation of the Minister of Agriculture and Agricultural Reform of January 20, 1945 issued for this purpose (Journal of Laws No. 4, item 16) defines the following: 'as the basis for the calculation of compensation for forest parcels, expropriated on the basis of art. 3 of the decree, their value is assumed, which will be determined by capitalizing the average annual income using the interest rate of deposits guaranteed by the state'. However, this applied only to forests with an area of less than 25 ha taken over on the basis of a decision first of the Minister of Agriculture and Agricultural Reform, and later by the Minister of Forestry (Piszczek 1949). Unfortunately, the nationalization of forests over 25 ha, with some exceptions, was conducted with no compensation.

In the initial phase of the so-called socialist economic era, the very sense of setting a value on a forest was negated. It was assumed that the forest is a free gift of nature, and its economy begins with the use of the existing standing timber resources. The revenues received from this should cover the costs of reproducing these resources. Each subsequent generation of the forest was established on the account of the previous generation, and hence, it has no value.

Countries with a capitalist economic system did not have such dilemmas in forestry economics, as evidenced by both the literature on the subject (Speidel, 1967) and the above-mentioned approach to determining the value of the forest. In this respect, nothing has changed. This is evidenced, for example, by the forest value guidelines used in Germany (WaldR, 2000), where the capitalization of forest income is recommended as the method to establish the value of a managed forest or even larger forests (Schuster 1992; Brabänder, Finckenstein 1993; Schmid 2004). These methods have also been recognized in the Polish literature on forest economics (Podgórski et al. 2001; Zając 2013).

3.2. Elements of the income approach

The income approach to forest valuation, as already indicated above, was developed in the first half of the 19th century. As time passed, however, it was improved, based on, among others, applying the principle of continuous interest instead of the classic periodic interest rate – generally annual. Another premise of its modification was adjusting its income and expenses account to the variable non-harvest and harvest periods of the tree stand that occur in practice. As a result, today one can talk about different methods of determining the income value of the forest. Nevertheless, discussions of the income value of a forest always include such terms as: forest income, forest interest rate, prolongation, discounting, capitalization and capital. It is worth becoming more familiar with these terms, and also to note the principles for determining them.

1. **Forest income and its types**. The term income in economics formerly referred to as the income received from the so-called main factors of production, that is, those that cannot be freely multiplied, as is the case with land, and thus also the forest. This is where the name 'land income', common in agriculture, and forest income in forestry are derived. Over time, however, synonymous terms like clear income, net income, profit or financial surplus have been used, also in forestry, instead of income. The opposite process was also occurring, and today, the concept of income in finances is sometimes applied to profit, dividends, wages and so on.

Forest income can vary and affect a forest manager in different periods depending on the principles and methods used to organize forest management and production. Therefore, the basic differences between several categories of forest income require explanation due to the different approaches to their capitalization. In this respect, the ideal and simultaneously the simplest situation is when you have a normal forest, characterized by tree stands of all age levels, in rectangular plots and stable in terms of the individual line items of income and expenses. As a result, such a forest as no other ensures the universality of implementing the principles of sustainability, continuity and uniformity of forest production and the permanent maintenance of the land under forest cultivation (Jedliński 1947). The income received from such a forest is obtained annually at a constant amount and for an infinitely long period of time. In short, it is said to have the character of a perpetual annual annuity (Moog 2007). In the case of small forest areas and the accumulation of

harvesting due to periodic logging, for example, every 5, 10 or more years, the income is not received every year, but rather after a certain longer period of time. Then it has the character of a perpetual cyclical (periodic) annuity.

Such a situation, in the opinion of the Poznań Land Credit Association occurred in relation to a forest with an area of less than 100 ha in a seed plantation and in those with an area of 50 ha in a coppice system plantation. Such a forest did not constitute 'independent forest management' and was not taken into account as collateral when granting loans (Newelski 1936). However, this did not exclude the possibility and need for its valuation, if only for its sale. On the other hand, the Act of December 28, 1925 on the implementation of land reform did not include the parcelling of forests suitable for 'independent management with an area of over 30 ha', and 'over 50 ha' in the region of the north-eastern voivodships (Ruśkiewicz 1931b). The small area cited of independent forest management indicates that there was a perpetual annuity also in this case, which was probably generally periodic.

Apart from forestry and agriculture, income having a finite period of flow dominates as the result of wear and the end of the utilization period of a given economic object. This may also occur in forestry but only sporadically, for example, as the result of changing the land use category of a forest. Such income is referred to as interrupted income (Jarosz et al. 1972), finite income (Institut für Agrar ...), or temporary income (Podgórska, Klimkowska 2005).

2. **Forest income accounting.** Due to the fact that forest management encompasses large areas in which there are stands of all age classes, starting from seedlings to mature stands ready for felling, annual perpetual annuity accounting is characteristic in forestry. The value of such an income stream (R) in traditional terms is (Speidel 1967):

$$R = A_u + D_a + D_b + \ldots + D_n - (c + u \,.\, v) \qquad (1)$$

where:

A_u – the value of annual harvestable products at age u after deducting expenses (in brief: net income from harvested timber),

D_a, D_b,..., D_n – the value of annual inter-harvestable products obtained from stands at age $a, b, \ldots, n$ years after the deduction of expenses (in brief: net income from inter-harvestable land),

c – costs of forest stand renewal together with tree crop maintenance and protection,

v – broadly understood average annual management costs (administration, taxes, depreciation, etc.) per one calculation plot of a normal forest (surface area unit of calculation),

u – harvesting age and at the same time, the number of calculation plots (surface area units) of a normal forest.

The calculation of forest income R does not present major problems when the forest area as measured in hectares is equal to the applied harvesting age (successive logging schedule). In this situation, the area of one calculation unit is 1 ha, so it coincides with financial and accounting data that is also calculated per 1 ha of forest. This is the case, for example, when u = 100 years and the forest area (H) is 100 ha. In the absence of such concurrence, all future income and expenses relating to forest management concern plots of land larger or smaller than 1 ha (formula 1). In a normal forest, and this is what we must assume due to the lack of information on the actual age class structure of a tree stand growing for many years, the area of one calculation plot h_j is equal to all degrees of age j = 1, 2, ..., u, and is (ha):

$$h = h_j = \frac{H}{u} \qquad (2)$$

wherein:

$$H = h \cdot u = \sum_{i=1}^{n} h_j$$

By now, taking the data from the forest management accounts on all income (A_u', D_a', ..., D_n') and expenses (c' and v') re-calculated per 1 ha of forest and multiplying this by h, the actual values of the elements of formula (1) are obtained, needed to determine the annual perpetual annuity.

Only in the case of management costs (v) is the procedure somewhat different, as these costs in formula (1) are referenced to the entire area of the managed forest resulting from multiplying their value attributable to one calculation unit of area (h) by the number of such units in the managed forest (u). This means that by referencing the accounting data on management costs to 1 ha of forest, you then multiply this by the area of the forest (H) to obtain the amount of the discussed expenses for the entire forest holding.

The determined income is the monetary reflection of the benefits of using the forest in the situation under discussion (a normal forest) for every year and over an infinite amount of time. In turn, from an economic point of view, the forest is a property with a specific monetary value, also called the value of forest capital from which a forest income is obtained. The ratio between net income and the value of the forest is the rate of return or profitability of the forest asset (capital). It is described by the formula:

$$p = \frac{R}{W} \qquad (3)$$

which in percentage terms of the forest rate of return, takes the form of:

$$p = \frac{R}{W} \cdot 100\% \qquad (4)$$

This formula consists of three factors:

- forest capital representing the value of the forest (W),
- instalment of forest income (R), which is called interest in percentage accounts,
- interest rate (p).

Factor W should be calculated according to the formula:

$$W = R \cdot \frac{100}{p} = \frac{R}{\frac{p}{100}} = \frac{R}{0.0p} = \frac{Au + Da + \ldots + Dn - (c + u \cdot v)}{0.0p} \quad (5)$$

The denominator of 0.0 p, which makes sense when $p <$ 10, has been widely used for 150 years in forest literature, which justifies using it in this study as well. Therefore, it is an equation with two unknowns, because forest income (R) can be determined without any major problem on the basis of data derived from the accounting system of forest management. Of the two unknowns contained in formula (5), the lack of the market value of the forest (W) forces the forest interest rate (p) to be assumed in advance. There are many reasons for this. Above all, the extensive amount of literature in this field containing many arguments and calculation results accumulated over 150 years indicate the adoption of such a forest interest rate and not a different one (Guttenberg 1950; Ackermann 1994; Zydroń et al. 2012; Adamowicz 2018).

3**. Forest interest rate**. One of the interesting methods of calculating the interest rate was proposed by Brabänder, using a formula for the financial equilibrium of a forest with a periodic harvesting schedule (Brabänder 1994):

$$A_u + D_a \cdot 1.0p^{u-a} + \ldots + D_n \cdot 1.0p^{u-n} = c \cdot 1.0p^u + \frac{v}{0.0p} - (1.0p^u - 1) \quad (6)$$

The left side of formula (6) has elements of future income streams, which can be obtained from harvest-ready timber (A_u) and work on pre-harvest (D_n) tree stands. Because they refer to standing timber, they are determined on the basis of the sales prices minus harvesting costs. The right side includes the costs of stand renewal and maintenance (c) and the administrative costs of the forest holding (v). The difference between the sides of the equation (6) is determined by the net income (forest income). Its calculation requires choosing such an internal (forest) interest rate, so that the income and expenses financed by the harvesting age are equal. Unfortunately, this equation cannot be solved analytically. However, one can obtain an estimated result using the method of successive approximations (iteration). This method is also recommended in financial mathematics to calculate the internal interest rate of any investment project (Podgórska, Klimkowska 2005).

The forest interest rate calculated in this way obviously depends on the amount of income and costs of the forest holding. These economic categories have a close relationship to the species composition of the forest, habitat, site index, forest management systems used, harvesting age of the tree stands and so on. In general, however, as the literature on the subject indicates, the discussed forest interest rate is at a level of 3% and is lower than the national interest rate (Speidel 1967; Oesten, Roeder 2001). Such a rate of interest was also recommended in the provisions of the Land tax of land holdings of 1935 for the Land Credit Association in Warsaw. A slightly higher, 3.3% rate, was used by the Poznań Land Credit Association (Newelski, 1936). The available sources show that the highest interest rate, at a level of 4%, was used for the valuation of forests in Saxony (Schmid 2004).

Using a lower forest interest rate is justified by the following considerations and benefits of owning a forest (Speidel 1967):

- low intensity of forest production (ratio of volume growth to abundance of forest stands in the holding) and the slight increase in the price for wood in the longer term,
- low risk of investing in a forest holding, enabling economic crashes to be avoided when compared to other investment options,
- the ability to quickly increase the acquisition and sale of wood when the forest owner is facing a critical economic situation,
- benefits of the prestige of belonging to the honourable group of forest owners.

However, these benefits do not always compensate for the low forest interest rate or determine the economic attractiveness of investing capital in forests. This is currently happening in many western European countries due to the close to zero or even negative profitability of forestry production. This is why the preferential forest sales in the eastern German states were subsidized by the federal government in the amount of 250 DM/ha for their management (Brabänder, Finckenstein 1993), while in the remaining cases, it generally required having adequate funds allocated for this purpose.

In view of the above considerations and recommendations included in the literature, as well as solutions applied in the past and present in other countries, it is perfectly reasonable to adopt a forest interest rate of 1–3% when valuing forests. There are many reasons for such a rate of interest. First, it provides a sustainable and low-risk return on capital represented by the forest, especially when compared to other investment options, including bank deposits. Second, reducing the forest interest rate will increase the capital value of the forest, but at the same time it will encourage the partial or total withdrawal of forest capital by increasing inter-harvesting and harvesting use of the land. Third, any increase in the forest interest rate at the same value of the its net income will result in a decrease of the capital value of the forest, and thus, will lead to abandoning efforts to properly manage it.

3.3. Formulas for the capitalization of a perpetual annuity

The above explanations allow us to present methods for determining the value of a forest based on the adopted forest interest rate (p) and the calculated value of forest income (R). The scope of these methods is limited here only to the perpetual annuity due to the legally binding principle of forest sustainability. Therefore, the periodic annuity obtained only

when the land is temporarily maintained as a tree plantation due to a planned change of its use category was omitted.

Within the framework of a perpetual annuity, the selection of forest valuation methods depends in turn on the frequency of its inflow. It can be received annually, as in the case of a normal forest, represented by stands of all one-year age classes, or over a certain longer period of time when the forest meets the general conditions of a harvestable timber plantation (age classes), because its structure, having, for example, 20-year age classes, is consistent with an even distribution (Klocek, Rutkowski 1986); however, harvesting (the main source of income) occurs every 5 or every 10 or 20, or even more years. The forest-based income then has a cyclical (periodic) perpetual nature. This is due to the total removal of the oldest age class stand in a single harvest. For example, if the forest area consisting of forest stands of the first five 20-year age classes has 100 ha, whereas the legally permissible area of harvesting used by its owner is up to 20 ha, and the age of the trees to be harvested is 100 years, then the income from one cycle of harvesting will be received only 5 times, or once every 20 years.

Irrespective of the above, the income may be received, depending on the forest harvesting schedule and the expectations of its owners, at the end or beginning of each period (annual or longer). In the first case, the income is paid in arrears, that is, at the end of each period; in the second case, the income is paid in advance, that is, at the beginning of the period when it is determined. If the situation of a specific forest holding and the expectations of its owner are unknown in terms of when the income is expected, then it is assumed that the income will be received in arrears, in accordance with the following logical sequence: renewal – maintenance, use and income are determined at the end of the year. Nevertheless, it is worth presenting the capitalization methods for all the categories of forest income listed above.

1. **The value of the forest when the perpetual annual forest annuity (net income) is received (paid) in arrears.**

The functional dependence for this income between its amount (R), forest interest rate (p) and forest value (W) is reflected by formula (7):

$$R = W \cdot \frac{p}{100} = W \cdot 0.0p \tag{7}$$

Therefore, the value of the forest (W) is:

$$p = \frac{R}{0.0p} = \frac{A_u + D_a + \ldots + D_n - (c + u \cdot v)}{0.0p} \tag{8}$$

The higher the forest income and the smaller the forest interest rate, the higher the value of the forest.

2. **The value of the forest when the perpetual annual forest annuity (net income) is received (paid) in advance.**

With this type of annuity, its value received at the end of the year should be discounted at the beginning of the year, or multiplied by the annual discount rate:

$$\frac{1}{1 + 0.0p} = \frac{1}{1.0p} \tag{9}$$

thus we obtain:

$$R = W \cdot 0.0p \cdot \frac{1}{1.0p}$$

and:

$$W = R \cdot \frac{1.0p}{0.0p} \tag{10}$$

It follows from the foregoing that the difference between the forest annuity received in advance and in arrears is:

$$\Delta R = R \cdot 1.0p - R = R\,(1.0p - 1) = R \cdot 0.0p$$

and so it is higher by the annual interest rate $R \cdot 0.0p$ from this annuity. Therefore, the value of the forest when the annuity is received in advance is slightly higher than when the annuity is received in arrears in accordance with the maxim: 'the zloty received today is worth more than the zloty received tomorrow'. This saying reveals the role of the interest rate as a factor balancing financial events that take place at different times.

3. **The value of the forest when the perpetual periodic forest annuity (net income) is received in arrears.**

Periodic harvesting occurs when the tree stands do not reach maturity in each year. In this case, the forest owner waits until the oldest tree stand increases in value to a level appropriate for this maturity. From an economic point of view, this process means accumulating yearly increases in value in accordance with the principle of compound interest 'growth in a given year increases growth in the next year' and so on. Therefore, if the current stand value is W_0, then after one year, it will increase to the level of:

$$W_1 = W_0 + W_0 \cdot 0.0p = W_0 \cdot (1 + 0.0p) = W_0 \cdot 1.0p$$

and after two years it will reach the amount:

$$W_2 = W_1 + W_1 \cdot 0.0p = W_1 \cdot (1 + 0.0p) = W_1 \cdot 1.0p = W_0 \cdot 1.0p^2$$

Generally, after n years of waiting for final harvest maturity, the amount will be:

$$W_n = W_0 \cdot 1.0p^n \tag{11}$$

Thus, in the period of n years, the increase in the value of the forest represented by the perpetual periodic annuity is determined with the following formula:

$$R = W_n - W_0 = W_0 \cdot 1.0p^n - W_0 = W_0\,(1.0p^n - 1)$$

in general, therefore:

$$R = W \cdot 1.0p^n - W = W \cdot (1.0p^n - 1) \tag{12}$$

However, the forest will reach the value of:

$$W = \frac{R}{1.0p^n - 1} \tag{13}$$

when the income is received in arrears, that is, at the end of the period. Formula (13) shows that the longer the breaks in harvesting the forest, the lower its value.

4. **The value of the forest when the perpetual periodic forest annuity (net income) is received in advance.**

As in the case of the annual annuity, the periodic annuity should also be discounted at the beginning of period *n*. Multiplying the right side of equation (12) by the discount factor ($1/1.0p^n$) we obtain:

$$R = \frac{W \cdot (1.0p^n - 1)}{1.0p^n}$$

and the resulting forest value:

$$W = \frac{R \cdot 1.0p^n}{1.0p^n - 1} \quad (14)$$

For the forest annuity received in advance, that is, at the beginning of period *n*, the waiting time for this annuity is zero, therefore its amount, and thus also the value of the forest, is higher than in the case of the annuity received at the end of period *n*.

In conclusion, we should mention the so-called expert method of forest valuation. In general, this is a combination of the methods presented above, depending on the views and knowledge of the appraiser and available figures. In addition, it should also be added that the presented methods do not relate to the valuation of a one-off loss or a periodic decrease in the value of the tree stand, or compensation for temporary damage to another component of the assets of a forest holding. On the other hand, they can be used to calculate compensation for a permanent or periodic reduction of income from the forest, for example, due to its inclusion in strict forms of nature protection, limiting the intensity of forest management, and thus, lowering its net income (profitability) value.

Conflict of interest

The authors declare the lack of potential conflicts of interest.

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