Taxation indices of forest stand as the basis for cadastral valuation of forestlands

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Abstract. Cadastral valuation of forestlands is one of the problems of the modern economy. Valuation procedures depend either on the profitability of timbering or forest areas are not differentiated according to value. The authors propose the procedure based on taxation indices of strata. The most important factors influencing the valuation are determined. The dependence that allows establishing the relative cost of a certain forest area is defined. Knowing the cadastral value of a model area, it is possible to determine the values of all other sites. The evaluation results correlate with the Faustman procedure with slight difference in the absolute value.

Introduction

Forest has traditionally been one of the most important natural resources in many European countries: Russia [1, 2], Turkey [3], Italy [4], Greece [5], Romania [6], etc. Only Russian forest lands occupy 1.104 billion hectares or 64% of the total area of the country and are not available for private ownership. [7] Forestry planning is aimed at creating a reasonable balance between the real wood cutting and its reproduction [8], as well as its protecting [9]. Charges for forest use, which are obtained in the form of rent, or fees under the contract of sale must offset the costs of caring for and recovery of forest plantations [10, 11]. Planning tool, rationalization and economic development, environmental protection[12], as well as the basis for forest management is called cadastre [13]. Since the beginning of the 80s the forestland has been described in space and time in the framework of the cadastral systems adopted in different countries.

Cadastral valuation procedure defining the cadastral value of parcels includes the following:

1.Making a list of real estate items; 2. Gathering information about the market value; 3. Analysis of factors determining the value of property; 4. Processing graphic information; 5. Modelling; 6. Calculation of the cadastral value; 7. Economic analysis of cadastral valuation results. The information about the cadastral valuation is relevant at least for two years. Nowadays not only a visual inspection is used for cadastral valuation, but also the latest scientific technologies (digital maps based on aerial photographs and photogrammetric method. To calculate probable value of a parcel it is desirable to provide evaluation using different procedures. The comparative analysis of the procedures results, the analysis of accuracy and influence on the final value allows getting quite accurate results. The procedures planned for calculation should be practical and efficient.

In Russia, two procedures are mainly used for cadastral valuation of forest lands. The first procedure (2002) estimates the parcels in accordance with probable profits that can be earned from them, based on the capitalization of land rent. [7] It is convenient from economic point of view, but is applicable only when the use of a forest area can draw profit. After the crisis in Russia in 2008 logging became unprofitable. Calculations according to this method make the cadastral value negative or close to zero. There was no sense in this procedure. It was cancelled by the Government of the Russian Federation in 2010. A specific value of one hectare of forest land is used today as an alternative to the cancelled procedure. This value is unified for the whole country, which is certainly convenient for practical use. But we can hardly speak about any differentiation of forest lands according to the value.

The aim of this research is to develop an accurate cadastral valuation of forest lands on the basis of taxation indices of forest stand.

Objects and methods of research

The basis for calculating the cadastral value of forest lands are the taxation indices of forest stand which are determined by conventional forestry techniques. The diameters were measured by the Swedish calliper MontaxComputer, and the height of the trees was measured by the hypsometer made in Germany by Blume-Leyss. The age of trees was determined with the help of age defining auger. The age class was calculated according to the average age. The stand density was determined by the Bitterlich's angle gauge. The merchantability class was calculated according to the percentage of the merchantable timber output. The quality class was determined on the basis of M.M. Orlov's evaluation tables. The forest stand was calculated using the tables of timber volume depending on the height quality class. The storey composition was determined according to the percentage of each wood species in the foreststand. Usually the data for cadastral valuation are presented in a form that is uncomfortable for statistical processing. So, they were reorganized at the preparatory stage. Table 1 shows an example of an electronic form of forest management documentation (a sample of 100 plots at Kurortnyi forest park, Saint-Petersburg).

Table 1. Taxation indices of forest stand on stratum № 1 presented in the electronic form.

Stratum №	Wood species, age	Storey	Height, m	Diameter, m	Age class	Merchantability class	Quality class	Density	Stand, m^3		Stock on stratum, m^3	
S, ha		Average height, m			Age group			Foresttype	per 1 ha	Total	Deadwood	Debris-strewn forest
Year of inventory								Forest site type	On stratum	By species		
1	6E - 5	1	20	24	4	1	2	0,7	232	27	2	2
0,2	1C - 5	--	19	24	--	1	-	KS	--	5	---	---
2013	3Б - 50	19	18	18	2	2	-	S2	46	14	-	1

The following factors in table 1 were used as taxation indices: ***stratum number*** – serial number of the forest area in the compartment (it is convenient to use it for objects numbering); ***square of the land area*** (ha) (important information, however, when comparing objects some relative indices are required, square is not applicable here; in addition, the square size of a target site is considered in the index "Total stock of timber"); ***year of inventory*** *determines the relevance* of the given information, however, since all strata are recorded during one season, there is no need to use this index. If taxation indices were determined at different period of time, it is possible to make age corrections; *wood species and their age* – in this column NX indicates wood species, where N is a relative part of the specie in the forest stand in tens of percent, X is the abbreviated name of the specie. The average age of a particular species in the stratum is indicated through a hyphen. These indices are definitely among the most important ones because they help determine the composition of the forest stand, which due to the different cost of timber directly affects the final value of the forestland. Age also allows scheduling some economic activities in the forest stand (improvement thinning, final felling, sanitary felling, etc.); ***stand of timber*** is a key index to assess the economic attractiveness of this or that strata, values dependent on this index are also given in the column; ***height (m), diameter (cm)*** are the parameters describing the average shape and size of the tree trunks in the stratum. They play an important role in determining the specific purpose of wood - for example, whether to use it as a fireplace wood, or as a commercial wood; ***age class***, merchantability class, quality class are estimated values calculated on the basis of the values of other factors and statistically making no contribution to valuation; ***the amount of deadwood and debris-strewn forest (m^3)*** comprises the non-merchantable wood. As a rule, it is quite small and does not affect the valuation significantly.

Thus, a set of factors for each stratum is presented in table 2. The data analysis shows that there are a lot of factors to be considered and their full use makes the model inconvenient and unsustainable. Then we considered the average indices of forest stand age and diameter. To be more precise, the obtained parameters were calculated as average values for each species (table 3).

Table 2. Factors influencing the cadastral valuation of the forestlands with different forest stand composition (fragment).

Stra-tum №	Forest stand composition*, fractions				Age, years				Diameter, cm				Storey height, m	Stand, m^3/ha
	B	Al	F	P	B	Al	F	P	B	Al	F	P		
1	0,5	0,5	0	0	55	55	-	-	18	20	-	-	17	124
2	0,5	0,5	0	0	65	65	-	-	20	22	-	-	18	136
3	0	1	0	0	-	70	-	-		24	-	-	18	136
4	0,3	0,7	0	0	55	35	-	-	16	18	-	-	16	93

*NB. Forest stand composition: B – birch, Al – alder, F – fir tree, P – pine tree, As – aspen

Table 3. Factors influencing the cadastral valuation of the forestlands (fragment).

Stra-tum №	Forest stand composition*, fractions					Age, years	Diameter,	Storey height, m	Stand, m^3/ha
	B	Al	F	P	As				
1	0,5	0,5	0	0	0	55	19	17	124
2	0,5	0,5	0	0	0	65	21	18	136
3	0	1	0	0	0	70	24	18	136
4	0,3	0,7	0	0	0	41	17,4	16	93

*NB. Forest stand composition: B – birch, Al – alder, F – fir tree, P – pine tree, As – aspen

After selecting the factors that can be used in a mathematical model for cadastral value calculation, it is necessary to determine the correlation ratio between them, since the correlation between the factors significantly reduces the accuracy of the results. The correlation matrix is presented in table 4.

The correlation matrix allows revealing a close connection (| R |> 0,6) between the factors. The correlation ratio between the fraction of birch and pine tree content in the forest stand is 0.74, which is caused by the competition between these tree species. This should be taken into account when developing the model. Such taxation indices as the average diameter, age, height and stand are mutually interconnected. Their correlation ratios range from 0.69 to 0.90. It is obvious that these 4 factors are interrelated – the maturity stands are higher and have a large stock of wood, than the young ones. Thus, it is relevant to exclude the average diameter and height of the stand from the model, as these parameters are closely related to the other two - the age and stand volume. It should be noted that the economic attractiveness of some forest area is determined by the stand index, which greatly depends on the factors mentioned.

Table 4. Correlation matrix

Indices	Timber species*					Age	Dia-meter	Height	Stand
	B	Al	F	P	As				
B	1								
Al	0,020	1							
F	-0,194	-0,146	1						
P	-0,742	-0,378	-0,303	1					
As	0,402	-0,077	-0,116	-0,451	1				
Age	-0,390	0,057	0,271	0,221	-0,428	1			
Diameter	-0,312	0,103	0,419	0,027	-0,281	0,838	1		
Height	-0,155	0,019	0,369	-0,073	-0,093	0,763	0,903	1	
Stand	-0,461	-0,244	0,494	0,272	-0,331	0,691	0,734	0,773	1

*NB. Forest stand composition: B – birch, Al – alder, F – fir tree, P – pine tree, As – aspen

The next stage of research is getting the factor or a system of factors that would reflect the composition of stands without overloading the model by excessive information. If the conifers prevail in the forest stand composition, it leads to the increase of the timber stock. If the broadleaved trees predominate, it reduces the timber stock. Therefore the whole forest stand can be divided into two corresponding groups. The unit of measurement will be the unit fraction. To use both fractions of conifers and broadleaved trees as two factors simultaneously is not reasonable because they are completely collinear (one can always be expressed in terms of the other). So, the fraction of the conifers may be used as the main index to reflect the structural composition of the forest stand on the stratum (table 5).

Table 5. The final set of factors influencing the cadastral valuation of the forest stand (fragment)

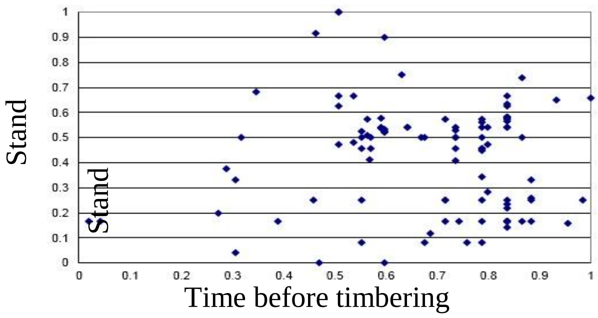
Stratum №	Conifer fraction	Age, year	Stand, m^3/ha
1	0	55	124
2	0	65	136
3	0	70	136

The basic data show that the vast majority of the stand has not reached the maturity stage. So the key parameter is not the age but the remaining time before reaching the age of maturity, i.e. the difference between maturity age and real age. For broadleaved trees the age of maturity is 60 years and for conifers it is 80 years. From the obtained data the weighted average time to start timbering was determined as the sum of productions of time before timbering the conifers and broadleaved trees and their fracture in the stand. To form to a unified system of measurements and correct recording of the distances between the factors the obtained data were standardized by the division of each value of the factor by the maximum value in the sample. The maximum stand of raw wood, taken as a unit, is found at the 34th stratum and equals 268 m^3/ha. Since the value dependence on time before timbering is inverse, it is turned into direct dependence for the convenience of calculations. To do this, all the standardized values obtained were subtracted from a unit and turned into reciprocal values. The index of the coniferous trees proportion in the stand composition essentially contributes to the cost of one cubic meter of wood. Thus, it can be taken into account only after all the basic calculations. According to the Federal State Statistics Service for 2013 one cubic meter of softwood round timber is 1.14 times more expensive than a cubic meter of hardwood. This difference is not spontaneous. It can be traced since 1998 on a regular basis. Then index that increases the value of wood for the broadleaf stand is 1, and 1.14 for the coniferous stand. For the mixed stand the formula will be the following:

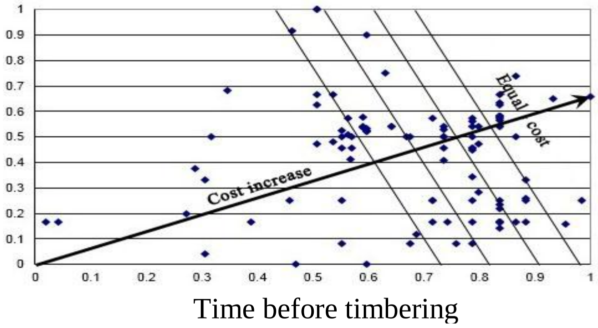
$k = 1 + f \cdot 1{,}14$,

where:
k – index that increases the value of the stand;
j – conifer fraction in the forest stand.

Thus, after excluding the proportion of coniferous trees, there are still two taxation indices affecting the cadastral value. These are time before timbering and stand. The known values for each stratum can be projected onto a plane, so that the stand is marked on the Y-axis, and the time before timbering is marked on the X-axis (figure 1.1). The heights above the axis mark the cadastral value of the stratum. The direction of the regression line projection was determined at the next stage. It describes the dependence of the parcel value on two taxation factors. It should be noted that the maximum cost is common for the forestlands with little time left before timbering and maximum stand. So these strata are marked in the upper right part of the point cloud. It is obvious that the minimum cost is common for the forestlands where the stand tends to zero and the maximum time before timbering. Thus, we can draw the assumed regression line projection as the connection of the corresponding points (figure1.2).



1.1



1.2

Figure 1.1. Point cloud on the plane. **1.2.** Cost line projection on the plane.

In this case, the segment length between the origin of coordinates and the point of intersection of the perpendicular dropped from the point with the values of the certain stratum factors with the cost line projection on the plane will be the geometrical expression of the forestland value (f).

The segment length is calculated according to the following formula

$f = y \cdot \sin(\varphi) + x \cdot \cos(\varphi)$, where:

f – the segment length expressing the cost;
x – on the X-axis, equals to the standardized time before timbering;
y – on the Y-axis, equals to the standardized stand;
φ – the inclination angle of the cost line projection.

The calculated value of ***f*** for each stratum is multiplied by the value index ***k***. Then these values are standardized by dividing them by the maximum value for forestlands. As a result the relative cost values (table 6) are calculated, which are fractions of the model stratum, the value of which is taken as a unit (in this case, it is stratum № 34).

In order to validate these results the same forestlands were evaluated using the procedure developed in 2002. Indices related to the economic activity of the enterprise were excluded from formulas, in particular the costs of transportation and timber processing, i.e. the value was determined only on the basis of income from timbering. The cost per one cubic meter of hardwood round timber was 1232 rubles, and the cost per one cubic meter of softwood round timber was 1407 rubles (according to the data of the Federal State Statistics Service in 2013). The capitalization ratio was set at 0,014. The cadastral values obtained were standardized by dividing by the value of the most valuable stratum (stratum № 34). The values of the forestland value, obtained with the help of different procedures, correlate quite closely, R = 0,732.

Table 6. Standardization of the relative cost index.

Stratum №	Relative cost index	Standardized relative cost index
1	0.689354	0.577137
2	0.686628	0.574855
3	0.726742	0.608439
4	0.649571	0.543831

Conclusion

Thus, the procedure described in the given paper characterizes the degree of change in value of the forestlands in the same way as the procedure developed in 2002. But the main difference is that the capitalization ratio is not used in the Principle component analyses. It is based purely on taxation indices of the forest stand for each forestland (stratum) in the forestry.

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