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METHODOLOGY FOR ESTIMATING THE VOLUME OF WOOD FOR PELLETS PRODUCTION WHEN GROWING POPLAR BY SHORT ROTATION FORESTRY ON THE LAND PLOTS OF COAL ENTERPRISES

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Abstract. The main topic of the study is the prospects of using the area of industrial sites of mining enterprises, together with the area of the corresponding protection and exclusion zones, as energy plantations with a short rotation of felling (Short Rotation Forestry) or with a short rotation of pruning (Short Rotation Coppice). The purpose of the study is to develop a methodology for determining the conditional yield of wood from energy plantations in the conditions of coal enterprises. The study uses a statistical analysis of the results of growing seedlings and cuttings of nineteen poplar varieties in the first years of life, which were published in the open scientific literature. We established the dynamics of changes in the diameters and trunk heights of the poplar seedlings under consideration in time that is characteristic of Short Rotation Forestry and Short Rotation Coppice technologies and is not taken into account when taxing forest stands in conventional non-energy forestry. The results of statistical processing and analysis showed that there are two modes, 21 and 44 cm, in the height distribution of one-year-old poplar seedlings, while the height distribution of two-year-old seedlings has only one mode, 150 cm. For distribution of poplar seedlings growth in the second year, one mode of 107 cm is observed. It was found that the dynamics of relative values of heights and diameters of trunks of 4-year-old poplar seedlings, as well as the relative volume of the trunk of these seedlings, during the first three years is described by an exponential function with a positive exponent. The uniformity of the formulas for the relative values of trunk heights and diameters allowed us to establish a power law relationship between these two parameters. The dependencies for calculating the possible wood yield for a land plot when used as an energy plantation were obtained, taking into account the geometric dimensions of the plot, the peculiarities of seedling placement and their number, the volume of the seedling trunk at the time of planting, the survival rate of trees and the term of felling. The exponential dependence of the conditional wood yield on the years after planting justifies the prospects of using forestry technologies with a short felling rotation, the so-called Short Rotation Forestry and Short Rotation Coppice, as this allows to obtain 104% more pellets in the second year than in the first, and 316% more in the third year.

Keywords: coal enterprises, pellets, Short Rotation Forestry, wood yield, plantation density.

1. Introduction

Over the 120 years of the Ukrainian coal industry's existence, coal has been mined at 276 mines and enriched at 61 coal processing plants. In the 21st century, most of these enterprises are out of business, creating so-called depressed regions that have been the subject of scientific and public debate for the past 25 years. The experience of other European countries, such as Germany and the Great Britain, which started closing coal enterprises 40 years earlier than Ukraine, shows that it takes much longer to solve environmental problems with the state of the land where coal mines and coal processing plants are located after their closure, as well as other problems of the so-called depressed regions where these enterprises were located. This experience points to the need to address these problems jointly, when a solution is implemented that simultaneously improves the environmental condition, facilitates the utilization of coal preparation waste, eliminates the effects of man-made impacts and creates new jobs. Today, it is clear that options for such a solution need to be developed in advance, before coal enterprises lose their production and social capabilities. Over the past ten years, the European and national scientific community has an opinion that this problem cannot be solved without the use of biotechnology, which allows for water and land purification, production of cleaner fuels, does not require a sufficient number of

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personnel, and facilitates the gradual re-profiling of enterprises. For example, there are examples of biotechnology used to drain mine water ponds and coal preparation waste storage facilities [1, 2], when the shores of these reservoirs are planted with willow, poplar, miscanthus, switchgrass, perennial sida or paulownia [3–7], which helps to increase the volume of moisture removal through aspiration. Some experts recommend using higher aquatic plants and shrubs for this purpose [3–5].

A common disadvantage of most biotechnologies proposed for use in coal mining is the problem of utilizing plant residues. The most natural way to solve this problem is to burn them or use them in the production of fuel based on the solid fraction of coal preparation waste or local wood [3, 8–11]. The most natural way to solve this problem is to burn them or use them in fuel production of fuel based on the solid fraction of coal enrichment waste or local wood [3, 8–11]. For the cultivation of this wood, the areas of industrial sites of coal enterprises can be used, together with the area of the relevant protection zone and exclusion zone. In EU countries, such as Germany, Poland, Sweden, and Denmark, there are examples of such land use, the so-called energy forests or energy plantations [4, 12–15], the wood from which is used to make biofuels in the form of pellets [12, 14, 16–17]. Industrial sites of coal industry enterprises have a certain potential in the form of land area that needs to be prepared for the extraction of man-made deposits, dewatering and preparation for reclamation (Table 1). All of these operations can be performed using biotechnology based on planting various plants that are raw materials for pellet production. After all, when an energy plantation is created near a waste storage facility, coal preparation creates an additional source of biofuel, which can be supplemented by plant residues used in biotechnology. The biofuel itself can be used to utilize coal preparation waste residues in the form of water-coal fuel in fluidized bed boilers [8, 18–20]. However, there are no examples of the organization of such energy plantations in the conditions of coal enterprises for such purposes, and traditionally their industrial sites are not considered by foreign and national experts for such purposes.

Table 1 – Approximate areas of industrial sites of coal enterprises in Ukraine

Name of the enterprise	Area, ha
Cheliuskintsev mine	9.50
SOJSC Kalynivska-Skhidna Mine	10.02
SE Nova mine	12.05
SE Rodynska mine	16.94
Trudivska mine	17.93
Mine "5/6"	21.13
SE Bulavynska Mine	21.33
OJSC Kurakhivska Mine	26.63
SE Pivnichna Mine	27.75
OJSC 1/3 Novohrodivska Mine	29.30
SE Petrovska Mine	29.57
SE Kalinina Mine	29.90
SE Horkoho Mine	23.40
SE Tsentralna Mine	32.20
Kocheharka Mine	32.90

continuation of table 1.2

Name of the enterprise	Area, ha
SE Mine Administration Aleksandrivske	34.20
SOJSC Novohrodivska Mine No. 2	34.29
SE Toretska Mine	36.68
SE Lidiivka Mine	36.83
SE Kuibyshevska Mine	37.12
SE Komsomolets Mine	37.60
SE Vuhlehirska Mine	37.60
OJSC Pioner Mine	40.90
Skochynskyi Mine	43.02
OJSC V.M. Bazhanov Mine	43.12
OJSC Yasynivska Hlyboka Mine	45.90
OJSC K.I. Pochenkov Mine	55.15
E.T. Abakumov mine	56.90
SE Olkhovatska Mine	57.10
V.I. Lenin Mine	59.10
OJSC Pivnichna Mine	63.00
SE Pivdenna Mine	73.60
Mospynska Mine	75.10
Mine "Ukraine"	76.92
OJSC Kholodna Balka Mine	77.46
OJSC S.M. Kirov Mine	80.98
Sviato-Pokrovska Mine	103.20
OJSC D.S. Korotchenko Mine	108.84
SE Yunyi Kommunar Mine	114.24
SE Oleksndr-Zakhid Mine	132.80
OJSC Belytska Mine "Zhovtneva" Central Processing Facility	152.40
OJSC Zhovtneva Mine	203.17
OJSC Almazna Mine	209.20
OJSC Dobropilska Mine	365.43

To justify such a decision in the design development of modernization of coal enterprises, it is necessary to estimate the volume of wood for pellet production when growing trees by the method of short felling on the land plots of coal enterprises. Therefore, the aim of the work is to develop a methodology for determining the volume of wood that can be grown by short felling on land plots of this type.

2. Methods

It is clear that the volume of wood for pellet production is directly proportional to the sum of the volume of tree trunks grown on the site. Plantation stock is the sum of the volume of tree trunks measured in m^3 per 1 ha [10, 12, 21–23]. In conventional, i.e. non-energy forestry, there are special species-specific tables of values of stocks and sums of cross-sectional areas of trunks at fullness of 1.0, depending on the average height of the plantation. These tables exist for different types of trees, which also takes into account the type of soil on which the forest grows. When using such a table, it is necessary to determine the average height and fullness of a given stand, which allows you to find the appropriate reserve value, the product of which with the fullness of a given stand determines the reserve value in a particular case. But these tables usually start with a trunk height of more than 12 m or 8 years of growth, which corresponds to a so-called long rotation period (Table 2), or a high felling rotation. It does not correspond to the conditions of energy forests, which are characterized by mini-rotation and forestry with a short rotation felling, Short Rotation Forestry (SRF), or with a short rotation of pruning, Short Rotation Coppice (SRC), (Tables 2 – 4) [17, 24]. It is these conditions, when wood is harvested during the first three years, that are supposed to be applied to plantations at industrial sites of coal industry enterprises.

Table 2 – Estimated placement of planting sites when creating energy plantations of various species of poplar in Ukraine [17, 24]

Type of plantation	Biomass harvesting cycle, year	Distance between plants, m		The number of plants, thousand units/ha
		between the rows	in the line	
Mini-rotation	1	0.7	from 0.40 to 0.70	from 20.4 to 35.7
	2	0.8	from 0.40 to 0.80	from 15.6 to 31.3
	3	1.0	from 0.30 to 1.00	from 10.0 to 33.3
	4	2.0	from 0.50 to 1.00	from 5.0 to 10.0
	5	2.5	from 0.40 to 1.00	from 4.0 to 10.0
With a long rotation period	10	from 2.0 до 2.5	from 2.0 to 3.0	from 1.3 to 2.5
	15	3.0	from 2.0 to 3.0	from 1.1 to 1.7
	20	3.5	from 2.0 to 3.5	from 0.8 to 1.4
	25	4.0	from 2.0 to 4.0	from 0.6 to 1.3

Table 3 – Technologies for growing energy poplar [24]

Type of plantation	Felling turnover	Planting density, thousand plants/ha	Harvesting after year	The diameter of the trunk, cm
I	very fast	to 10	1	from 2 to 3
II	fast	from 10 to 15	from 2 to 3	from 10 to 12
III	medium	from 1.3 to 3	from 5 to 6	to 15

Table 4 – Italian distribution of poplar energy plantations by rotation age [17, 24]

Type of felling	Harvesting after year	Planting	distance in m between			Planting density, thousand plants /ha	Stem diameter, cm
			group of rows	of rows	of plants		
very short	1	in 2 rows	1.8	0.75	0.45	from 10 до 13	from 2 to 8
short	from 2 to 3	in 1 row	–	3	from 0.5 to 0.6	from 6 to 7	from 10 to 12
medium	from 5 to 6	in 1 row	–	3	from 2 to 2.5	from 1.3 to 1.7	15

Poplar was chosen to create a methodology for calculating the volume of wood as an example because poplar has the average growth rate among all the trees that were selected, namely, paulownia, willow, poplar, miscanthus, switchgrass, and perennial sida. Pavlovnia has the highest growth rate of these trees, which is most often used to obtain raw materials for pellet production [6, 7].

SRF and SRC are the most intensive methods of woody biomass production. SRF involves growing trees in an intensive manner in order to maximize yield and productivity in the shortest possible time [25, 26]. At the same time, after the trees from SRF have been cut down, they are often allowed to regenerate from stumps into a young grove, the so-called SRC.

Given the specifics of these technologies, we have chosen the following research methodology. To develop a methodology for calculating the sum of the volume of tree trunks of an energy plantation using the geometric characteristics of seedlings and taking into account possible geometric parameters of their planting. To identify possible species and types of trees that can be planted on energy plantations. To obtain statistical data for these species on changes in geometric parameters during the first two years of life. To propose a methodology for determining the conditional yield of wood from energy plantations in the conditions of coal enterprises.

3. Theoretical part

For the conditions of energy forests, especially SRF or SRC, or energy plantations that are planned to be created on the land plots of former coal mining enterprises, it would be more rational to calculate the sum of tree trunks volumes using the formula (1):

$$O = \omega \cdot n \cdot s \cdot h \cdot f \,, \tag{1}$$

where O – the sum of the volumes of tree trunks on the plantation, m^3; ω – the survival rate of the tree variety (Table 5) [24]; n – the number of trees on the plantation, pcs; s – the cross-sectional area at a trunk height of 1.3 m, m^2; h – the height of the tree, m; f – the value of the species number, which can be in the range from 0.352 to 0.592 [26].

Table 5 – Survival rates of some poplar varieties [24]

Variety of poplars	Survival rate, %	
	Minimum	Maximum
Dorskamp	41.7	85.3
Robusta	12.5	20.0
I-45/51	20.0	28.3
Topohrytskoho	35.0	48.3

The number of trees on the plantation is determined by the number of plants per unit area, thousand pcs/ha, planting density, thousand plants /ha, or the feeding area of one tree, m^2 (Tables 6, 7) [13, 15–17, 24–26] therefore, it would be rational to rewrite formula (1) in the following form:

$$O = \omega \cdot \Gamma \cdot s \cdot h \cdot f \cdot F \,, \tag{2}$$

$$\Gamma = \frac{n}{F} \,, \tag{3}$$

where Γ – planting density (tables 6, 7); F – area of the energy plantation.

Low-grade hardwood species are grown for the energy sector, as the energetic and chemical processing of coniferous woody biomass in gas generating units at temperatures above 800°C leads to the formation of physiological resin components that cause difficulties in the operation of the power supply system of internal combustion engines.

Table 6 – Classification of poplar plantings by the UN FAO Commission [13, 15–17, 24–26]

Planting type	Feeding area of one tree, m^2
Very dense	less than 10
Dense	from 10 to 25
Medium dense	from 25 to 35
Normal dense	from 35 to 45
Sparse	from 45 to 60
Very sparse	more than 60

Table 7 – Number of seedlings per 1 ha for row planting, pcs. [24]

Distance between seedlings in rows, m	Distance between rows, m				
	2.5	3.0	3.5	4.0	4.5
1.0	4000	3300	2900	2500	2200
1.5	2668	2201	1934	1668	1467
2.0	2200	1650	1450	1250	1100
2.5	1600	1320	1160	1000	880

To date, there are about 20 species of fast-growing plants that can be grown to produce plant biomass for bioenergy. The most promising species are bird cherry, walnut, lodgepole pine, viburnum, pyramidal poplar, willow, birch, acacia, ash, sycamore, alder, which are characterized by the most intensive growth and gain their full height in a year, which is from 0.5 to 2 m [15, 16, 17, 21, 23, 24, 27–30]. Domestic experts point out that for southern Ukraine, willow is 20% more efficient than any other tree as an energy source. However, poplar is more desirable for biofuel production than many other woody crops, given its rapid growth, ability to produce significant amounts of biomass in a short period of time, and high cellulose and low lignin content.

There are known results of studying the diameters and trunk heights of some poplar varieties, namely Sakrau 79, Arrowhead, Robusta 16, Rosyiska, Addita, Karolinska 162, Volosistoploda, Verila, Slava Ukrayiny, Ivanteevska, Versiya, Perspektivna, Lubenska, Sakrau, Glory, Vereecken, Blanc du Poitou, Dorskamp, Keliberdinska, grown from seedlings and cuttings, in the first few years of life (Table 8, Fig. 1–5) [24].

Table 8 – Height characteristics of annual poplar seedlings, cm [24]

Name of the variety	Average value	Minimum value	Maximum value	Possible deviation
Dorskamp	176.8	154.1	228.6	74.5
Robusta	134.7	94.3	207.9	113.6
I-45/51	131.6	87.1	154.3	67.2
Topohrytskyi	167.0	106.2	217.6	111.4
Average value	152.5	110.4	202.1	91.7
Coefficient of variation, %	12.7	19.8	11.8	22.7

These results indicate the existence of two modes, 21 and 44 cm, in the height distribution of one-year-old poplar seedlings (Fig. 1), while the height distribution of two-year-old seedlings already has only one mode, 150 cm (Fig. 2). The same pattern is observed for the distribution of poplar seedling growth in the second year, i.e. there is one mode located closer to the left border - 107 cm (Fig. 3).

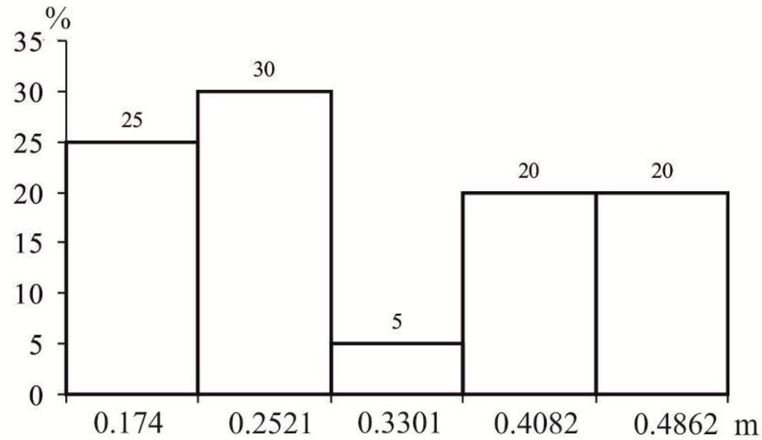

Figure 1 – Histogram of the height distribution of one-year-old poplar seedlings from cuttings of the Ukrainian Research Institute of Forestry and Forest Melioration (URIFFM) breeding laboratory [17, 24]

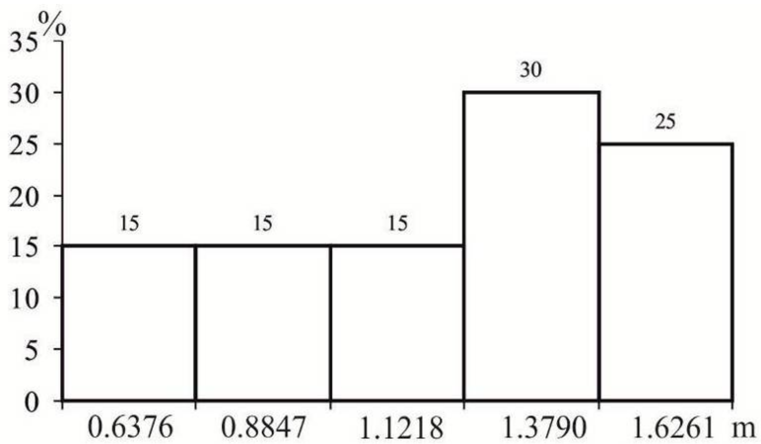

Figure 2 – Histogram of height distribution of two-year-old poplar seedlings from cuttings of the URIFFM breeding laboratory [17, 24]

Numerical processing of the results of these studies indicates that for almost 80% of the known poplar varieties, the height of seedlings in the second year is 4 times higher than their height in the first year (Fig. 4), and the growth of seedlings in the second year does not exceed their height in the first year by 3 times (Fig. 5). At the same time, the following formula (2) is valid for all the above poplar varieties:

$$\frac{h_2}{h_2 - h_1} = 1.358 \pm 0.101, \quad (4)$$

where h_2 – height of two-year-old seedlings, m; h_1 – height of one-year-old seedlings, m.

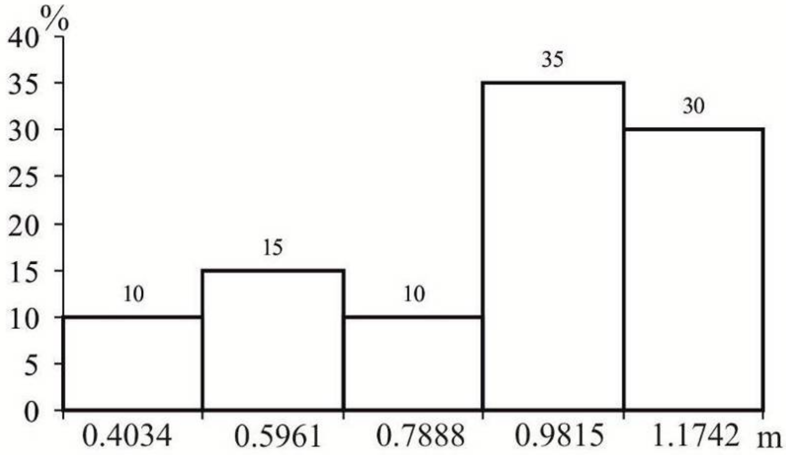

Figure 3 – Histogram of the distribution of growth of poplar seedlings in the second year from cuttings [17, 24]

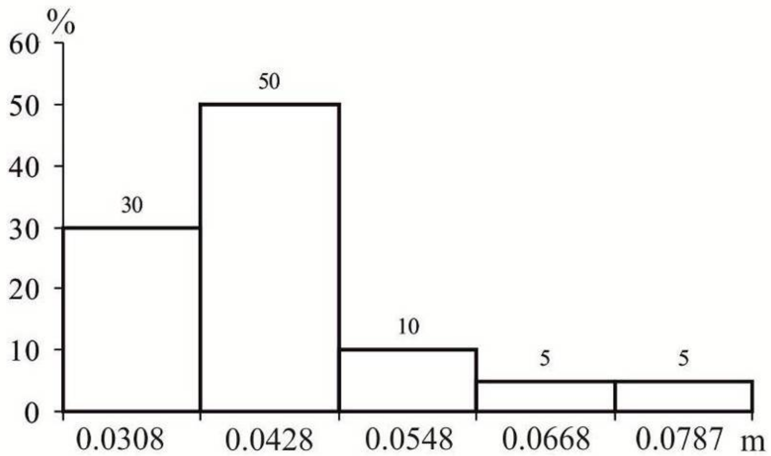

Figure 4 – Histogram of the ratio of the height of two-year-old poplar seedlings to their height in the first year for cuttings of the URIFFM breeding laboratory

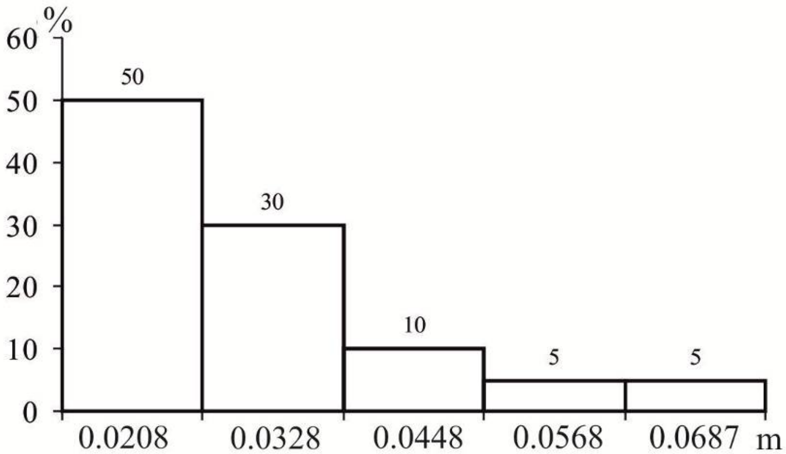

Figure 5 – Histogram of the ratio of poplar seedling growth in the second year to their height in the first year for cuttings of the URIFFM breeding laboratory

A more in-depth study of the dependence of the height of two-year-old seedlings on their height at the end of the first year allowed us to divide the known poplar varieties into two groups with different growth intensities (figs. 6, 7). The first group of varieties includes: Sakrau 79, Arrowhead, Robusta 16, Rosyiska, Addita, Karolinska 162, Volosistoploda, Perspektivna, Lubenska, Glory, Vereecken, Blanc du Poitou. The second group of varieties includes: Verila, Slava Ukrayiny, Ivanteevska, Versiia, Sakrau, Dorskamp, Keliberdinska.

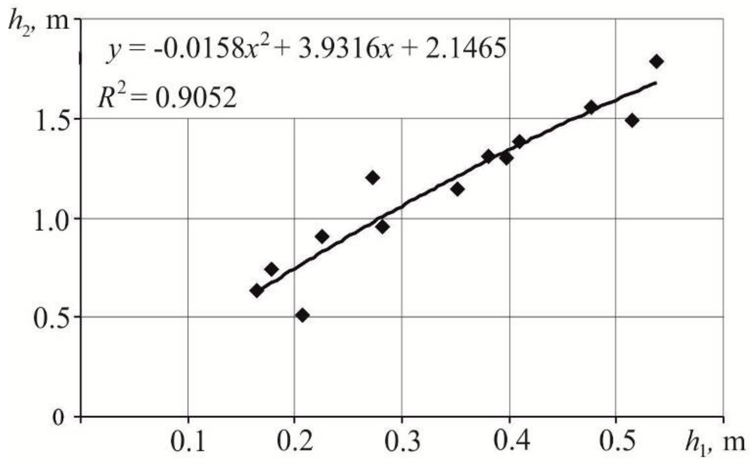

Figure 6 – Dependence of the height of two-year-old seedlings of the first group of poplar varieties on their height in the first year for cuttings

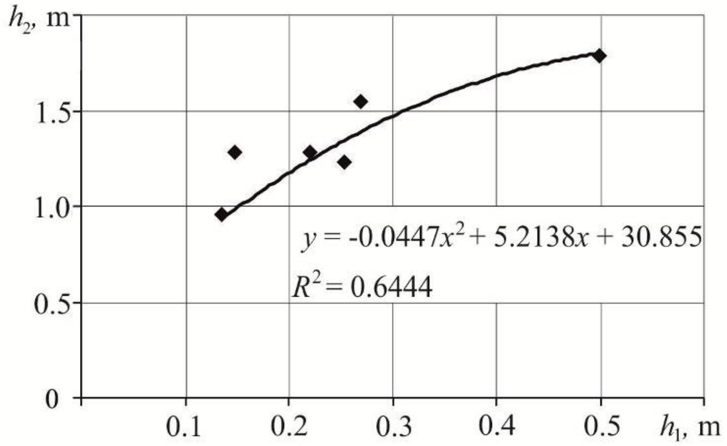

Figure 7 – Dependence of the height of two-year-old seedlings of the second group of poplar varieties on their height in the first year for cuttings

For each group, an approximation of the dependence of the height of two-year-old seedlings of the second group of poplar varieties on their height in the first year by a second-degree polynomial was obtained:

$$h_2'(h_1) = 2.147 + 3.932h_1 - 0.016h_1^2; \quad h_2''(h_1) = 30.855 + 5.214h_1 - 0.045h_1^2, \quad (5)$$

where h_2' – height of two-year-old seedlings of the first group of varieties, m; h_2'' –

height of two-year-old seedlings of the second group of varieties, m.

It was found that the seedlings of the second group of varieties in the second year have an increase of more than 40% than the seedlings of the first group. That is, the following relationship (6) exists between the dependence of the height of two-year-old poplar seedlings of the second group of varieties on their height in the first year of both groups of varieties:

$$h_2''(h_1) = (1.4 \pm 0.18) h_2'(h_1). \qquad (6)$$

The research results of biometric parameters of plants of 4-year-old poplar plantations during 2017–2019 [22] allow us to assess the statistical characteristics of the geometric parameters of seedlings (table 9), as well as to study the dynamics of the relative values of height and diameter of trunks (Fig. 8) using formulas (7):

$$\chi(i) = \frac{h(i)}{h(0)}, \; \delta(i) = \frac{d(i)}{d(0)}, \qquad (7)$$

this allowed us to obtain the following formulas (8)

$$\chi(i) = 1.0076\,e^{0.3244i}, \qquad \delta(i) = 1.018\,e^{0.5515i}, \qquad (8)$$

where χ – relative height of seedlings; h – height of seedlings in the year after planting, m; δ – relative diameter of the seedlings; d – diameter of seedlings in the year after planting, m; i – year number after planting seedlings, in the year of planting $i = 0$.

Table 9 – Dynamics of biometric parameters of plants of 4-year-old poplar plantations (2017–2019) [18, 23, 25]

Parameter	2017	2018	2019
Plant height, m	4.6/4.4	6.5/2.5	8.8/2.8
Diameter at a height of 30 cm, mm	25.7/15.9	47.0/6.5	77.3/4.0
Growth per year by height, m	–	1.9/8.4	2.3/8.2
Growth per year by diameter at a height of 30 cm, mm	–	30.3/4.0	21.3/14.4
Growth over two years by height, m	–	–	4.2/1.8
Growth in diameter over two years, mm	–	–	51.7/17.9

Notes. The numerator indicates the average value of the value, and the denominator indicates the coefficient of variation.

The similarity of the functions in formulas (5) and (6) indicates a functional relationship between the values of relative diameter and relative height of seedlings, which can be established on the basis of fig. 9 as an approximation of its power function (9):

$$\delta = \chi^{1.7}. \qquad (9)$$

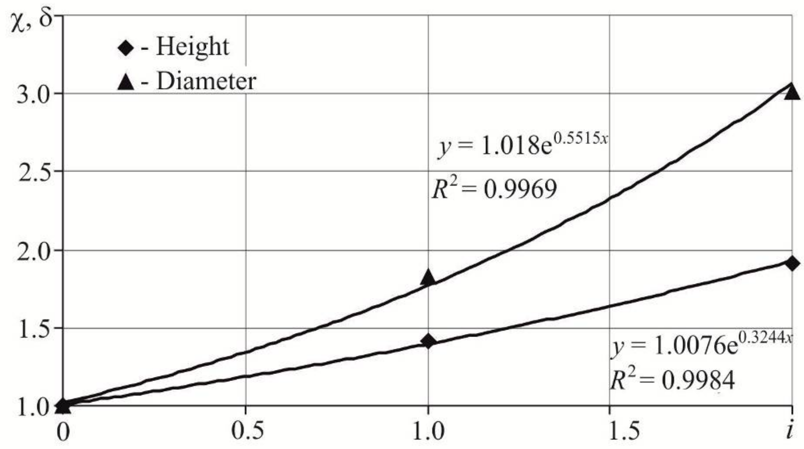

Figure 8 – Approximations of the dependence of relative trunk height and diameter on years of growth

Thus, considering together formulas (7)–(9), the dynamics of changes in the volume of the trunk of seedlings on energy plantations in the first year after planting can be determined as follows (10):

$$V(i) = \vartheta(i)V_0, \qquad \vartheta(i) = 1.034\,\mathrm{e}^{1.427i}, \tag{8}$$

wher V – volume of the trunk, m^3; V_0 – volume of seedling trunk at the time of planting, m^3; $\vartheta(i)$ – relative volume of the seedling trunk.

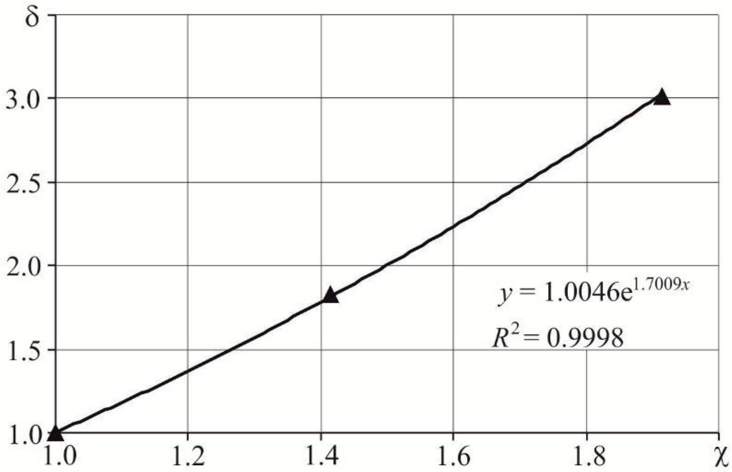

Figure 9 – Approximation of the dependence of the relative diameter of the trunks on the relative height

Using formulas (2), (3), (7) and (10), we obtain the following estimate for the sum of tree trunks on energy plantations (11):

$$q = 1.034 \cdot \omega \cdot \Gamma \cdot e^{1.427i}, \quad q = \frac{O}{F \cdot V_0}, \tag{11}$$

where q – conditional wood yield, O – sum of the volume of tree trunks on the plantation, m^3.

Thus, the first of the formulas (11) calculates the potential wood yield for a land plot when used as an energy plantation, taking into account the geometric dimensions of the plot, the specifics of seedling placement and their number, the volume of the seedling trunk at the time of planting, the survival rate of trees and the felling period.

The components of the first formula (11) and the value V_0 are elements of the tree planting technology and are chosen based on the best growing conditions on the soils where the coal industry enterprises were located. It follows that, given the selected values of the conditional wood yield and the volume of seedling trunks at the time of planting, the required volume of wood to provide the regulated volume of pellets can only be met at the expense of the industrial site area:

$$F_* \le F, \qquad F_* = \sigma \frac{O_*}{q \cdot V_0}, \tag{12}$$

where F_* – minimum allowable area of the industrial site; σ – space utilization rate, is always greater than one.

Approximate intervals of changes in the area of industrial sites of Ukrainian coal enterprises can be established on the basis of table 1. According to the requirements of statistical data processing, seven groups can be distinguished (table 10). The first group is the largest and most likely, and therefore should be considered separately and in more detail (figure 10). Fig. 10 shows that this group should be divided into three subgroups, which indicate the likely values of the area of industrial sites - not less than 9.5 hectares and not more than 46 hectares (fig. 11).

Table 10 – Distribution of sites of Ukrainian coal enterprises by area

Group	Industrial site area	Share, %
I	from 9.5 to 65 ha	70.21
II	from 65 to 121 ha	17.02
III	from 121 to 177 ha	4.26
IV	from 177 to 233 ha	6.38
V	from 233 to 289 ha	0.00
VI	from 289 to 345 ha	0.00
VII	from 345 to 365 ha	2.13

That is, for the conditions of land plots of domestic coal enterprises, it is necessary to consider the types of trees that provide a conditional wood yield of at least the following value

$$q_* = \sigma \frac{O_*}{46 \cdot V_0} 10^{-4}. \tag{13}$$

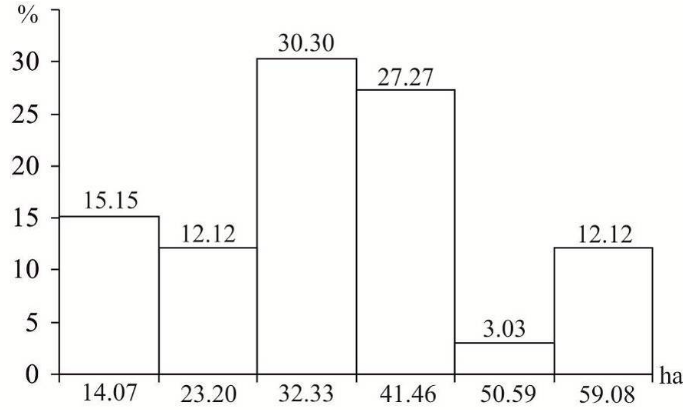

Figure 10 – Histogram of distribution of industrial sites in Group I by area in the group

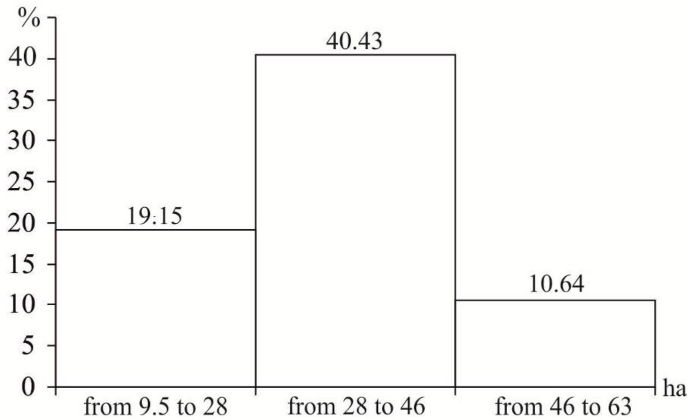

Figure 11 – Histogram of the total distribution of Group I industrial sites by area

3. Results and discussion

The results of the above formulae analysis lead to the following conclusions.

It was found that the dynamics of relative values of heights and diameters of trunks of 4-year-old poplar seedlings, as well as the relative volume of the trunk of these seedlings, during the first three years is described by an exponential function with a positive power law, formulas (8) and (10). The uniformity of the formulas for the relative values of trunk heights and diameters made it possible to establish a power law relationship between these two parameters, formula (9).

Given the exponential dependence of the conditional wood yield on the years after planting, we can say that the use of short rotation forestry technologies, the so-called SRF and SRC, allows us to obtain 104% more pellets in the second year of harvesting than in the first, and 316% more in the third year.

4. Conclusions

The article investigates the possibility of using land plots around coal enterprises as energy plantations and proposes a methodology for calculating the energy potential of such plantations.

An assessment of the distribution of industrial sites of Ukrainian coal industry enterprises by area was obtained, and it was proven that 70% of these sites have an area that does not exceed 65 ha. At the same time, the most probable interval of change in the area of a land plot that can be used for planting trees as an energy plantation is from 9.5 to 46 hectares with a probability of 40%.

The dependencies for calculating the possible wood yield for a land plot when used as an energy plantation are substantiated, taking into account the geometric dimensions of the plot, the specifics of seedling placement and their number, the volume of the seedling trunk at the time of planting, the survival rate of trees, and the felling period.

Conflict of interest

Authors state no conflict of interest.

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МЕТОДИКА ОЦІНЮВАННЯ ОБСЯГУ ДЕРЕВИНИ ДЛЯ ВИГОТОВЛЕННЯ ПЕЛЛЕТІВ ПРИ ВИРОЩУВАННІ ТОПОЛІ МЕТОДОМ КОРОТКОГО РУБАННЯ НА ЗЕМЕЛЬНИХ ДІЛЯНКАХ ВУГІЛЬНИХ ПІДПРИЄМСТВ

Слободянникова І., Тепла Т., Гальченко З., Кабакова Л., Буряк С.

Анотація. Предметом дослідження є потенційний об'єм деревини, який може бути отримано в умовах вугільних підприємств, з метою виготовлення пелетів або інших видів біопалива. Основною темою дослідження є перспективи використання площі промислових майданчиків гірничих підприємств разом з площею відповідної охоронної зони та зони відчуження, як енергетичних плантацій з коротким оборотом рубки (Short Rotation

Forestry) або з коротким оборотом обрізки (Short Rotation Coppice). Мета роботи полягає в розробці методики визначення умовного дебіту деревини з енергетичних плантацій в умовах вугільних підприємств. При дослідженні використовується статистичний аналіз результатів вирощення саджанців і живців дев'ятнадцяти сортів тополі на перших роках життя, які були опубліковані у відкритій науковій літературі. Це дозволило встановити динаміку змінення діаметрів та висоти стовбура саджанців сортів тополі, що розглядаються, в терміни, які характерні для технології Short Rotation Forestry та Short Rotation Coppice, та не враховуються при таксації лісових насаджень у звичайному неенергетичному лісництві. Результати статистичної обробки та аналізу вказують на існування двох мод, 21 та 44 см, в розподілі висот однорічних саджанців тополі, в той час, як розподіл висоти дворічних саджанців має лише одну моду – 150 см. Існування однієї моди, 107 см, спостерігається й для розподілу приросту саджанців тополі за другий рік. Встановлено, що динаміка відносних величин висот та діаметрів стовбурів 4-річних саджанців тополю, а також відносного об'єму стовбура цих саджанців, протягом перших трьох років описується експоненціальною функцією з додатним показником степені. Однотипність формул для відносних величин висот та діаметрів стовбурів дозволила встановити степеневу залежність між цими двома параметрами. Отримано залежності для обчислення можливого дебіту деревини для земельної ділянки при використанні її в якості енергетичних плантацій, що враховує геометричні розміри ділянки, особливості розміщення саджанців та їх кількість, об'єм стовбура саджанців на момент висадки, приживлюваність дерев та термін рубки. Експоненціальна залежність умовного дебіту деревини від років після висадки саджанців обґрунтовує перспективність використання технологій лісництва з коротким оборотом рубки, так званих Short Rotation Forestry та Short Rotation Coppice, оскільки це дозволяє при зборі деревини на другий рік отримати на 104 % більший обсяг пелетів, ніж в перший, та на 316 % – при зборі на третій рік.

Ключові слова: вугільні підприємства, пелети, лісництво з коротким оборотом рубки, дебіт деревини, щільність насадження.