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ANALYSIS OF THE SELECTED FACTORS INFLUENCING THE MANAGEMENT OF FOREST RESIDUES IN POLAND

ANALIZA WYBRANYCH CZYNNIKÓW WPŁYWAJĄCYCH NA ZAGOSPODAROWANIE POZOSTAŁOŚCI ZRĘBOWYCH W POLSCE

***Summary**: Modern energy management uses solid biomass in combustion processes with a great success. The amount of biomass increases along with properly conducted forest management, the development of agricultural production and the growing scale of post-production waste. Statistical analyses, determining the dependence of the factors on the tested parameter and also, supporting the priority of activities, may facilitate the development of certain pro-ecological activities in a given region. The article estimates the economic use of forest residues as a source of renewable energy fuel in the context of the market situation.*

The performed statistical analysis of multivariate ANOVA method and the AHP method as well, determined the possibilities to manage the forest residues for energetic purposes. In one case, the critical significance level determining the assignment of the analyzed factor to a particular homogeneous group was below 0.05. This means that there is a relationship between the number of public roads and the number of enterprises. Therefore, due to the number of roads, the greatest prospects for the development of a company in the wood industry are found in the Małopolskie, Mazowieckie, Śląskie and Wielkopolskie voivodeships.

***Keywords**: forest residues, energy management, biomass, forest management, wood industry*

***Streszczenie**: Współczesna gospodarka energetyczna z powodzeniem wykorzystuje biomasę stałą w procesach spalania. Ilość biomasy wzrasta, wraz z właściwie prowadzoną gospodarką leśną, rozwojem produkcji rolnej i rosnącą skalą odpadów poprodukcyjnych. Analizy statystycznych określające zależność czynników na badany parametr a także wspomagające priorytet działania mogą wspomóc rozwój pewnych działa proekologicznych na danym terenie. W ramach artykułu oszacowano ekonomiczne wykorzystanie pozostałości zrębowych jako źródła paliwa odnawialnego w kontekście sytuacji rynkowej.*

Przeprowadzona analiza statystyczna określiła możliwości zagospodarowania biomasy leśnej przeznaczonej na cele energetyczne, wykorzystując wieloczynnikową analizę wariancji ANOVA i metodę AHP. W jednym przypadku krytyczny poziom istotności decydujący o przypisaniu analizowanego czynnika do określonej grupy jednorodnej wynosił poniżej 0,05. Oznacza to, że istnieje zależność pomiędzy ilością dróg publicznych a liczbę przedsię-biorstw. W związku z powyższym, z uwagi na ilość dróg największa perspektywa rozwoju przedsiębiorstwa działającego w branży drzewnej istnieje w województwie małopolskim, mazowieckim, śląskim i wielkopolskim.

***Słowa kluczowe**: pozostałości zrębowe, gospodarka energetyczna, biomasa, gospodarka leśna, branża drzewna,*

Introduction

During the recent years, many improvements in respect of innovative ecological solutions have been carried out in the heating and energetic industries. It results from the duty of adapting the energetic policy to the assumptions of energy-climate package of the European Union. According to the binding legal legislation, a part of biomass is utilized in heat plants and power plants. The mentioned activities have a direct relationship with the reduction of greenhouse gases, utilizing the mechanisms, acting of the principle of clean development mechanism (CDM[1)]). The idea of limiting the unfavourable environmental changes was ratified within the frames of the UN Conference in Kyoto, contributing to resolution of Directive 2003/87/CE, limiting the exploitation and excessive use of fossil fuels.

Raw material

The chosen strategy inclines Poland as well as other countries, to deeper interest in the possibilities of managing and use of commonly available, pro-ecological waste raw materials from forest territories. The mentioned group includes material, generated on forest surfaces and the residues from

[1)] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003, establishing a scheme for greenhouse emission allowance trading within the Community amending Council Directive 96/61/CE p. 631

Tab. 1. The percentage of individual parts of wood in the total weight of pine

No.	Properties	Literature
1.	- longitudinal thickness: 64% - stacked thickness: 8% - general limb: 5% - brushwood: 7% - roots: 16%	[4]
2.	- wood arrows: 61% - bark arrows: 8% - branches: 12% - needles: 3% - snag: 16%	[1]
3.	- treetops, branches, needles: 20% - branches thinner than 40 mm and needles: 15% - branches thicker than 40 mm: 5%*	[1]
4.	- trunk 69% - top, branches 16% - stump, roots 15%	[8]

** Including the above-ground biomass part of the harvested wood*
Source: Own study

forest raw material-producing industry, being treated as a waste. The obtained forest residues, resulting from forest work, have been officially defined as forest biomass (Official Journal of Laws, 2015, item 317). This group consists of firewood in a form of chips and waste coming from forest in a form of small-dimension wood: branches, tops, bushes, brushwood and tree stumps, and also, wastes from wood industry (chips, sawdust). In relation to a part of the mentioned residues, we can observe the tendency of increasing the interest in the wastes which in the forest management until now have not been commonly used for heating and energetic purposes. The discussed forest residue as small-dimensional material was produced and used by the local inhabitants or sold for a symbolic sum.

The terminology of the described forest residues has not been consolidated. In literature, the mentioned material is described as logging residues, after-logging residues or slash [3]. The forestry residues are the material, remaining as a result of wood logging. In order to prepare the area for renovation, the branches and tops of the trees should be removed after felling (forest operations). They should be collected in piles on post-logging area or at exit routes. When disintegrated, they may be mixed with soil, using specialist machines. Forest residues are characterized by a high content of bark and needles.

According to literature data, the present area of forests in Poland covers about 9.2 million hectares. It corresponds to ca. 29.6% of the territory of our country. Climatic and habitat conditions are favourable for development of coniferous trees which constitutes 69.6% of the total afforestation [Wasiak 2014]. Common pine (*Pinus silvestris L*), being also called Scots pine [7] is most frequently found and acquired tree species in Polish forests. The potential of wood industry is expressed in its production functions. In Poland, 34352103 m^3 of total coniferous thickness are acquired annually [2].

During the process of wood acquiring, a big amount of waste is produced from which, *inter alia*, we may distinguish forest residues. The mentioned forest residues consist mainly of branches and tops of the trees. The participation of logging residues is differentiated and amount to ca. 15%. According to estimates, about 6 million m^3 of logging residues are generated during logging of 34 million m^3 of coniferous thickness. The preparation of wood material consists in fragmentation of the raw material to a form of wood chips, using disintegrator. The percentage participation of the particular wood parts in the total mass of pine, as described in literature, has been presented in Table 1.

The percentage participation of the particular wood parts in the total weight of pine, characterizes the amount of generated forest biomass as a result of thickness harvesting. The estimated quantity of forest residues inclines us to undertake the problem of their management. In practice, the forest residues may be left at the site of logging in a form of fertilizer; however, their utilization as a solid fuel allows producing the additional source of renewable energy. The undertaking of the action towards management of forest residues is justified by an insufficient amount of information on the possibilities of their economic utilization; carrying out the economic analysis would allow extending the information concerning the economic utilization of forest residues.

Economics

It is mentioned in literature that the entrepreneurship is a certain ability of utilizing the available technology, information, different types of resources and the management methods in order to achieve the intended aim. Utilization of disintegrated forest residues fits widely the idea of entrepreneurship as it may

Table 2. The selected data concerning the factors according to the particular voivodeships

Voivodeship	Number of enterprises	Coniferous wood acquisition, m³	Total public roads, km	EU funds,/ person
Dolnośląskie	2541	2 760 541	24 333,4	22
Kujawsko-pomorskie	1628	2 428 896	27 516,5	59
Lubelskie	1521	1 332 704	38 115,4	37
Lubuskie	1005	3 050 218	15 579,6	28
Łódzkie	2078	1 170 489	26 045,8	72
Małopolskie	5943	864 462	31 444,0	24
Mazowieckie	5095	1 865 031	55 008,5	49
Opolskie	1007	1 054 616	10 504,8	13
Podkarpackie	2285	1 583 928	21 122,9	30
Podlaskie	1008	1 626 952	26 673,5	63
Pomorskie	2154	4 801 999	22 720,0	30
Śląskie	4552	1 308 918	24 756,4	36
Świętokrzyskie	1059	1 108 281	17 491,7	20
Warmińsko-mazurskie	1105	2 669 944	22 360,0	46
Wielkopolskie	4661	3 336 411	41 042,1	69
Zachodniopomorskie	1533	3 388 714	19 849,3	16

Source: Main Statistical Bureau (GUS)

occur to be the undertaking with a high economic potential. Introduction of the conception of utilizing the disintegrated forest residues requires economic analysis which has been carried out in the present paper, using the available statistical tools. Table 2 includes the data, according to the voivodeships, which were used during the statistical analysis. The mentioned data describe the factors which may affect the development of the enterprises.

The aim and methodology of the studies

The aim of the study was to perform the statistical analysis of the possibilities to manage the forest biomass, destined for energy purposes. To analyze the selected factors, affecting the level of forest biomass management in Poland (as assumed), the statistical methods were used (ANOVA, AHP).

Statistical ANOVA analysis

To elaborate the statistical results, the analytical tools in a form of multi-factor variance analysis ANOVA were employed. The mentioned method allows determining the influence of the selected factors on the initial parameter and the mutual relationships between the analyzed parameters, with the assumption that the remaining factors are constant (unchanged) i.e. *ceteris paribus*. The mentioned relationship is expressed in formula 1.

$$\omega = f(\tau, \varphi) \tag{1}$$

During the analyses, value α, characterizing significance level and expressing the probability of performing the error in the choice of confidence coefficient, was considered [10][2]. The allocation of a given factor to a specified uniform group is determined by a critical confidence level. Value of test probability α was adopted on the level equal to 0.95, i.e. F=1-α. The results of the conducted statistical analysis were also affected by the nature of the problem and accuracy of the distribution of means [Statistics performed manually 2015; in Polish: "na piechotę"][3]. The definition of the resulting inter-group error consisted in determination of the ratio of the sum of inter-group squares and the number of freedom degrees[4]. The inter-group error may be determined, using formulae 2, 3 and 4.

$$SS_T = \sum_{i=1}^{a} m_i(\bar{y}_{(i.)} - \bar{y}_{(..)})^2 \tag{2}$$

[2] J. Jakubowski, R. Sztencel: Introduction to theory of probability, Script, Warsaw 2004, p. 59

[3] Manual statistics https://home.agh.edu.pl/~bartus/index.php?action=statystyka&subaction=przedziały_ufnosci

[4] http://www.naukowiec.org/wzory/statystyka/jednoczynnikowa-analiza-wariancji_371.html.

$$df_T = a - 1 \quad (3)$$

$$MS_T = \frac{SS_T}{df_T} \quad (4)$$

where:
m_i – number of units in the particular groups,
a – number of the groups under comparison in variance analysis, number of factor levels,
$\bar{y}_{(...)}$ – general mean, for all observations,
$\bar{y}_{(i...)}$ – the mean for a given level of factor, for the tested group,
SS_T – inter-object, inter-group sum of squares,
df_T – inter-object, inter-group degrees of freedom,
MS_T – inter-group variance.

The analysis of variance with multiple classification allowed examining the effect of the components on the population. Theoretical scheme of statistical analysis is shown in formula 5.

$$Xijk = xsr + ai + bj + ck + (ab)ij + (ac)ik + (bc)jk + (abc)ijk + eijkl \quad (5)$$

where:
X_{sr} – general mean, for the whole population,
ai – effect of A factor on level i (i=1, 2,....., n)
bi – effect of B factor on level i (i=1, 2,....., k)
ck – effect of C factor on level i (i=1, 2,....., m)
$(ab)ij$ – effect of interaction of A and B factors on the levels i and j, respectively
$(ac)ik$ – effect of interaction of A and C factors on the levels i and k, respectively
$(bc)jk$ – effect of B and C factors on the levels i, j and k, respectively
$(abc)ijk$ – effect of interaction of A, B and C factors on the levels I, j and k , respectively
$eijkl$ – random error with a normal distribution, mean equal to zero and constant variance.

AHP method

The definition of final results requires construction of the appropriate structure of the example to be solved, with modeling of the proper scheme of the problem's hierarchy. To develop the alternative to the choice from among the analyzed variants, the method, developed by Thomas Saaty, called AHP, was employed. The mentioned method requires the construction of the appropriate structure of the example to be solved with modeling of the scheme of the problem's hierarchy. During the analysis, all elements, constituting the matrix of the variable criteria, are compared. The accuracy of alternative of the solutions is increased proportionally to the degree of the proceeding in respect of the adopted scheme [10].

AHP method compares all elements, creating the matrix of variable criteria, expressing value of the specified traits. The assigned values of the elements will be plotted out and compared in the prepared square matrix. The specified traits correspond to the numerical values, assigned according to the priority recognition. During evaluation, the intermediate values and even reverse values are also admitted. The reciprocal occurs in the case when the second element is more important than the first one. The assignment of numerical values is facilitated owing to specially prepared nine-score grading scale, corresponding to the equivalent of the rank of the factors [5, Przybyło and Krężołek 2010]. Table 3 contains the standardized 9-score scale of gradation.

Table 3. Characteristics of the assessed objects according to Rycąbel

Importance degree	Explanation
1	Both elements have the same weight
3	The first element is a little more important than the second one
5	The first element is more important than the second one
7	The first element is much more important than the second one
9	The first element is decisively more important than the second one

Source: [11]

For development of the results, the counting module in a form of computer program, called AHP method was employed. The mentioned program was elaborated in the Delhi environment within the fames of the author's research activities. The discussed program has a designed counting module in a form of matrix algorithm, for diagnostic and comparative evaluation of the analyzed criteria. The analysis, employing AHP method, was conducted based on the selected factors affecting the management of the logging residues in Poland.

The results of the studies and conclusions

In the examined case, ANOVA analysis allows determining the effect of individual factors on the input parameter and, also, defining the mutual relationships between the analyzed parameters. The numerical interval, as estimated with the assumed probability as a confidence interval, contained the unknown, real value of the parameter, belonging to a general population, which characterized the vertical columns, having a range of 0.95. The confidence intervals may be determined for the arithmetical mean. The probability, specifying the real location of the defined parameters has been determined by confidence interval (1-α) (percentage confidence interval 100 (1-α))[5]. A critical level of significance, determining the assigning a

[5] Manual statistics http://home.agh.edu.pl/bartus/index.php?action=statystyka&subaction=przedzialy_ufnosci

given factor to the specified homogenous group should amount at least to less than 5%. As a result of the conducted estimates, three basic output parameters and factors were chosen. The analyzed parameters and output factors have been presented in Table 4.

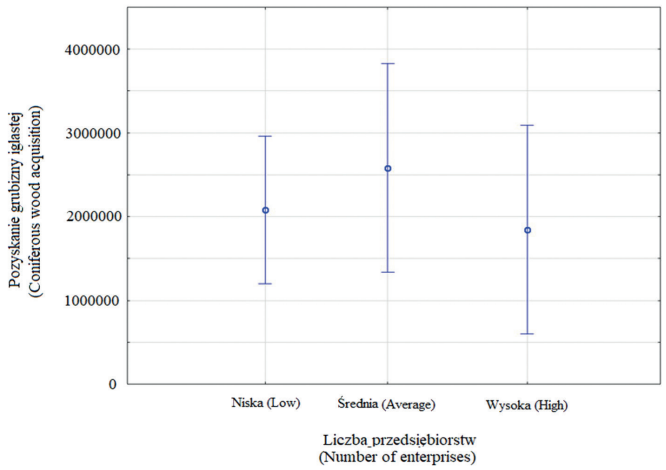
Table 4. The analyzed parameters and output factors

Output parameter	Factors
(Number of enterprises – subclass 16.29.Z, Manufacture of other wood products Grouping factor: • Low - < 2000 • Average 2000 ÷ 4000 • High > 4000	Coniferous wood acquisition, m^3
	Total public roads - hard and unpaved surface, km EU funds – RDP 2014–2020 – 6.4. Support for investments in the creation and development of non-agricultural activities), person

Source: Own study

As a result of statistical analysis (ANOVA), the impact of coniferous wood acquisition, length of public roads and the possibilities of additional financing from the EU means on the number of enterprises in wood material processing industry was determined. In the case of the effect of coniferous wood acquisition on the number of enterprises, the statistical analysis die not show any effect. The significance level was higher than 0.05 and had value p = 0.659. The empirical value of statistics was equal to F (2, 13) = 0.43139. The characteristic of the relationship between the number of the enterprises and coniferous wood acquisition is given in Fig. 1.

Fig. 1. Characteristics of the relationship between the number of enterprises and coniferous timber acquisition



A different situation occurred in the case of the number of enterprises and the quantity of roads. The level of significance: p= 0.034 where the empirical value of statistics F (2, 13) was equal to 4.4565. The statistical analysis showed the effect of the number of public roads on the number of enterprises. The characteristic of the relationship between the number of enterprises and the number of public roads is given in Fig. 2.

The result of Duncan analysis in the recent case showed a significant effect on the number of enterprises. It may be concluded that the discussed situation reveals a certain adaptation of transport in the voivodeships where there is a high development of enterprise in the field of wood material processing. The specified homogenous groups of the relationships between the number of enterprises and the number of public roads are illustrated in Table 5.

Fig. 2. Characteristic of the relationship between the number of the enterprises and the number of public roads

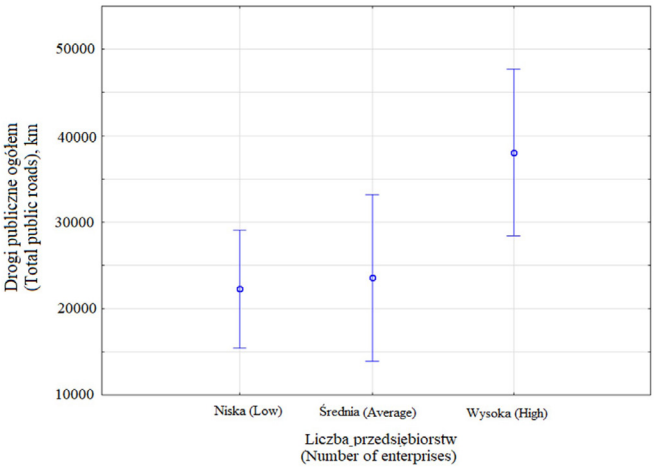


Table 5. The relationships between the number of enterprises and the number of public roads

Number of enterprises	Homogeneous group	
	I	II
Low	X	
Average	X	
High		X

Source: Own study

In the case of financing the undertaking with the utilization of the EU funds, statistical analysis did not found any significant effect on the studied factor on the number of the created enterprises. The statistical analysis revealed that the level of significance p = 0.759 for value of empirical statistics F (2, 13) was equal to 0.28230. The statistical analysis ANOVA did not show any effect of the quantity of allocated EU funds within action 6.4 (Support of investments in creating and development of non-agricultural activity) on the number of enterprises. The characteristic of the relationship between the number of enterprises and the amount of the allocated EU funds is given in Fig. 3.

According to the methodology, the application of hierarchic choice method (AHP) requires construction of square matrix together with the ascribed traits of the factors. In the upper right corner of the matrix, the declared values of the analysed traits should be marked. From the analysis of the results, we may conclude that the number of public roads with the hard ground

Fig. 3. Characteristics of the relationship between the number of enterprises and thre amount of the allocated EU funds

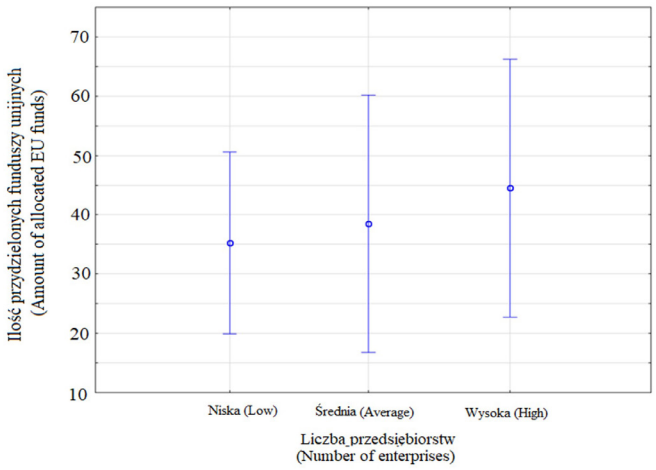


Fig. 4. Values of weights

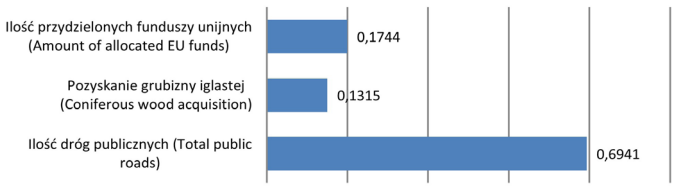


Table 6. Pairwise comparative matrix

Criteria preferences	IDP	PGI	IPFU
Total public roads	1	7	3
Coniferous wood acquisition	1/7	1	1
Amount of the allocated EU funds)	1/3	1	1

Source: Own study

and the dirt roads has the highest weight (impact) from among the analysed factors on the development of entrepreneurship.

We should remember that the selected example is a model as the potential development of the enterprise is determined by greater number of factors than those ones chosen to the given example. As a result of analysis it was established that the maximum own value of matrix was equal to 3.0803. The Consistency Index (CI) amounted to 0.0401499 what means that it satisfied the condition of consistency ($\lambda max - n) / (n - 1) \leq 0.1$). Values of weights are given in Fig. 4.

Observations and conclusions

The conducted analysis allowed formulating the following conclusions:

1. In Poland, there are quite big resources of material in a form of forest residues.
2. According to statistical analyses, there is a group of factors which may affect the development of enterprise in respect of management of the forest residues.
3. When starting a business activity in the field of wood chip processing, we should be driven by infrastructure of public roads. Statistical analysis showed that public roads with hard ground surface and the dirt roads are a significant factor in respect of wood waste processing.
4. According to grouping factor, the Małopolskie, Mazowieckie, Śląskie and Wielkopolskie voivodeships are the most developed regions in relation to the number of enterprises and public roads.

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